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GROWTH CHANGES IN THE CEPHALIC INDEX DURING THE FIRST FIVE YEARS OF LIFE

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THE head measures and cephalic indices which are reported here were obtained as a part of a larger investigation in which the same children were measured repeatedly during their growth from birth through early childhood. Most of the anthropometric measurements which were made have been described in a previous study (3) which gives a full account of the sample and the methods of measurement. In the present study we are concerned with the transverse and anterior-posterior head diameters, and the index obtained from them.

The children measured — 31 boys and 30 girls — are of white, English-speaking parentage, living in or near Berkeley, California. They are predominantly "Old Americans" largely of North European stock — mixtures of English, Scotch, Irish, German, Norwegian, Dane, Dutch; with thirteen of these cases reporting French, Spanish or Italian ancestry in small proportions. Three are of a pure North European nationality. One child is Mexican, probably with Indian blood.

With occasional exceptions (due to illness or absence from town) each child was measured once a month on or near his birth date during his first year, and at 15, 18, 24, 30, 36, 48, and 60 months of age. The data have been studied most completely for the period through 36 months, with the 48- and 60-month measures treated in less detail.

The method of measurement is the same as that described in the International Agreement, with the exception that before month 30 the procedure used at the Iowa Child Welfare Research Station (8) was followed in measuring head length — i. e. the nasion instead of the glabella was used as the anterior point. This procedure was followed because the nasion can be more accurately determined and held, in measuring a squirming infant. The data on the two head diameters and the cephalic index have been treated in the same manner as were the other body measures previously reported (3).

RELIABILITY OF MEASUREMENTS

The program of tests and observations made it impracticable to make repeated measurements at a single visit. The best available criteria of reliability, then, are coefficients of correlation between

TABLE 1

Self Correlations between Consecutive Measurings of the Head Diameters

AGE IN MONTHS	ANTERIOR-POSTERIOR		TRANSVERSE	
	No.	r	No.	r
1 × 2	49	.90	49	.85
2 × 3	56	.83	58	.85
3 × 4	57	.83	59	.90
4 × 5	55	.83	56	.93
5 × 6	52	.87	55	.91
6 × 7	48	.86	50	.93
7 × 8	44	.83	47	.96
8 × 9	44	.87	49	.94
9 × 10	42	.93	50	.96
10 × 11	37	.93	41	.97
11 × 12	43	.91	44	.95
12 × 15	52	.92	52	.94
15 × 18	48	.91	48	.95
18 × 24	42	.87	42	.95
24 × 30	41	.85	41	.94
30 × 36	46	.94	46	.95
36 × 48	44	.91	44	.97
48 × 60	42	.96	42	.97

measures taken at adjacent age levels. These correlations are given in Table 1. When we take into consideration the growth changes which occur from one age to the next, the measures appear to be very reliable, and similar in reliability to the measures of head circumference. The average of the correlations (for the first 36 months) between measures at adjacent age levels is .92 for head circumference, .93 for head width, and .88 for head length. The reliability coefficients of the three head measures are higher than for any of the other body measures of these children except weight and total length. A high reliability is to be expected, as the measures are made on rigid bony points having very little subcutaneous tissue. Head length is the less reliable of the two on young infants, as the head must be held firmly in place, and the anterior point is difficult to maintain while measuring an uncooperative infant.

As two different measurements were used in determining head length, it will be important to compare their relative reliability, and to discover the effects of shifting from one measure to another in making comparisons at different ages. The correlation coefficients between head length measures in which the glabella is used as the anterior point in both (beginning with months 30 by 36) tend to be higher than the reliabilities obtained when the nasion is used as the anterior

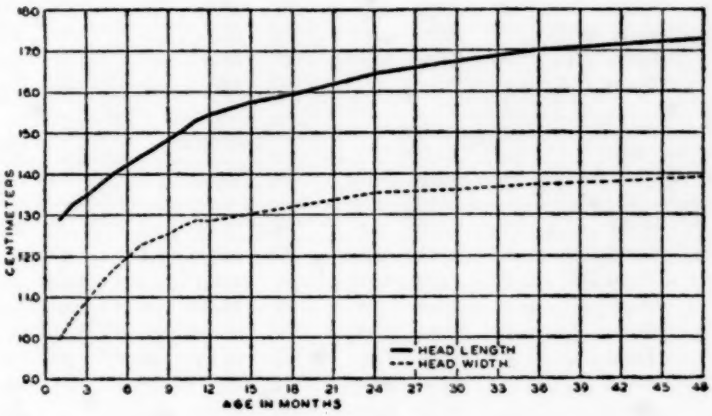

FIG. 1. CURVES OF MEANS FOR HEAD LENGTH AND HEAD WIDTH

TABLE 2

Means and Standard Deviations of the Transverse and Anterior-Posterior Diameters and the Cephalic Index from One through Thirty-Six Months

MEASURE	SEX	MONTH 1			MONTH 2			MONTH 3		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	24	13.10	.53	31	13.43	.39	30	13.70	.64
	Girls	26	12.74	.51	27	13.09	.58	29	13.29	.59
	Total	50	12.91	.58	58	13.27	.53	59	13.50	.64
Head Width	Boys	24	10.13	.40	31	10.61	.38	31	11.08	.39
	Girls	26	9.84	.45	27	10.35	.44	30	10.72	.48
	Total	50	9.98	.44	58	10.49	.41	61	10.90	.51
Cephalic Index	Boys	24	77.1	3.6	31	79.0	4.0	30	80.8	4.7
	Girls	26	77.2	5.0	27	78.9	5.6	29	80.5	5.8
	Total	50	77.2	3.9	58	79.0	4.4	59	80.6	5.7

MEASURE	SEX	MONTH 4			MONTH 5			MONTH 6		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	30	13.94	.63	29	14.31	.48	29	14.38	.47
	Girls	29	13.56	.63	27	13.73	.47	27	14.08	.50
	Total	59	13.76	.58	56	14.03	.56	56	14.23	.58
Head Width	Boys	30	11.51	.33	30	11.86	.51	30	12.22	.33
	Girls	29	11.15	.56	27	11.55	.56	28	11.75	.62
	Total	59	11.33	.53	57	11.71	.59	58	11.99	.58
Cephalic Index	Boys	30	82.6	4.5	29	82.7	4.7	29	84.9	4.5
	Girls	29	82.3	5.8	27	83.9	5.4	27	83.5	5.8
	Total	59	82.4	5.6	56	83.3	4.9	56	84.2	5.5

MEASURE	SEX	MONTH 7			MONTH 8			MONTH 9		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	26	14.67	.53	25	14.85	.43	25	15.06	.45
	Girls	24	14.20	.49	26	14.42	.46	26	14.66	.51
	Total	50	14.44	.62	51	14.63	.51	51	14.86	.46
Head Width	Boys	27	12.45	.43	25	12.68	.36	27	12.83	.41
	Girls	25	12.11	.57	27	12.19	.56	29	12.33	.62
	Total	52	12.29	.49	52	12.43	.48	56	12.57	.60
Cephalic Index	Boys	26	84.9	4.0	25	85.1	2.7	25	85.2	2.7
	Girls	24	85.1	5.2	26	84.6	4.9	26	83.8	5.6
	Total	50	85.0	4.6	51	84.8	4.5	51	84.5	4.4

TABLE 2—(*Continued*)

MEASURE	SEX	MONTH 10			MONTH 11			MONTH 12		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	25	15.30	.55	26	15.50	.36	28	15.68	.39
	Girls	21	14.81	.37	18	15.16	.53	27	15.28	.44
	Total	46	15.08	.48	44	15.36	.49	55	15.48	.52
Head Width	Boys	26	12.97	.39	26	13.08	.44	28	13.12	.47
	Girls	25	12.50	.56	19	12.61	.49	28	12.62	.58
	Total	51	12.74	.53	45	12.88	.54	56	12.87	.58
Cephalic Index	Boys	25	84.7	4.2	26	84.3	3.7	28	83.4	3.4
	Girls	21	85.0	5.2	18	83.3	5.6	27	82.2	4.5
	Total	46	84.9	4.1	44	83.9	4.5	55	82.8	4.1

MEASURE	SEX	MONTH 15			MONTH 18			MONTH 24		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	27	16.04	.38	24	16.23	.46	24	16.64	.45
	Girls	25	15.50	.58	24	15.76	.50	21	16.30	.59
	Total	52	15.78	.56	48	15.99	.61	45	16.48	.57
Head Width	Boys	27	13.28	.37	24	13.45	.41	24	13.76	.45
	Girls	25	12.77	.56	24	12.96	.51	21	13.28	.55
	Total	52	13.03	.59	48	13.20	.58	45	13.54	.50
Cephalic Index	Boys	27	82.6	3.6	24	82.7	2.2	24	82.5	2.6
	Girls	25	82.3	4.3	24	82.1	4.8	21	81.4	4.7
	Total	52	82.5	3.5	48	82.4	3.8	45	82.0	3.6

MEASURE	SEX	MONTH 30			MONTH 36			MONTH 48		
		No.	Mean	S. D.	No.	Mean	S. D.	No.	Mean	S. D.
Head Length	Boys	25	17.00	.55	25	17.22	.61	21	17.46	.56
	Girls	22	16.48	.51	24	16.78	.50	23	17.03	.48
	Total	47	16.76	.54	49	17.01	.51	44	17.23	.57
Head Width	Boys	25	13.89	.33	25	14.06	.35	21	14.19	.44
	Girls	22	13.30	.64	24	13.46	.48	23	13.66	.51
	Total	47	13.61	.62	49	13.76	.59	44	13.91	.55
Cephalic Index	Boys	25	81.6	2.6	25	81.4	3.2	21	81.1	3.3
	Girls	22	80.5	4.4	24	80.1	4.2	23	80.2	4.4
	Total	47	81.1	3.4	49	80.8	3.4	44	80.6	3.9

MEASURE	SEX	MONTH 60		
		No.	Mean	S. D.
Head Length	Boys	22	17.66	.55
	Girls	24	17.16	.50
	Total	46	17.40	.58
Head Width	Boys	22	14.33	.40
	Girls	24	13.78	.48
	Total	46	14.04	.52
Cephalic Index	Boys	22	81.3	3.2
	Girls	24	80.3	4.1
	Total	46	80.8	3.7

point, but not significantly higher than the highest of these. In regard to the comparability of the two measures, one point to be considered is the correlation between measures at adjacent ages in which the glabella was used at one age and the nasion at the other. Although the relationship between the measures at 24 and 30 months (.85) is not among the higher correlations, there are several lower correlations between consecutive measures in which both terms are taken from the nasio-occipital diameters. The diameter taken from the glabella should be expected to be larger than that taken from the nasion, but the relative head size of the children seems to change only slightly with this change in the measurement. With this qualification in mind, then, we may proceed to compare the measurements taken after 24 months with those taken earlier.

GROWTH OF HEAD LENGTH AND HEAD WIDTH

Figure 1 and Table 2 show that growth in size is comparatively rapid during the first year and very slow after this age, with deceleration in rate from birth through five years. In this respect these trends of growth are similar to those found for other body measurements on the same children (3). The two curves in Figure 1 are not parallel, however. Head width grows more rapidly during the first seven months, while head length grows more rapidly after eight months. In both measures, for all ages, the boys are slightly larger than the girls (Table 2). There is no trend with age in the sex difference in head length during the period studied; but in head width the difference tends to become greater with increasing age. The magnitudes of these sex differences are, on the average, similar to those reported by Wallis (12) for similar ages. She has shown that the sex differences in young children are much smaller than in adults.

CHANGES IN CEPHALIC INDEX

As would be expected from an observation of the varying rates of growth obtained for the two diameters, the cephalic index does not remain constant, but increases from birth to seven months and decreases after ten months (Figure 2 and Table 2). After month twelve the changes in the index are comparatively small, but consistent in their direction. Both sexes follow the same course of growth. The children at birth are relatively dolichocephalic, rapidly becoming brachycephalic until about seven months of age. After ten months the tendency is toward increasing dolichocephaly. This later trend is in

keeping with that found in other studies of age trends in cephalic index (5, 6, 7). Although there are only incomplete data in the literature on cephalic indices during the first year, those available tend to corroborate our findings.

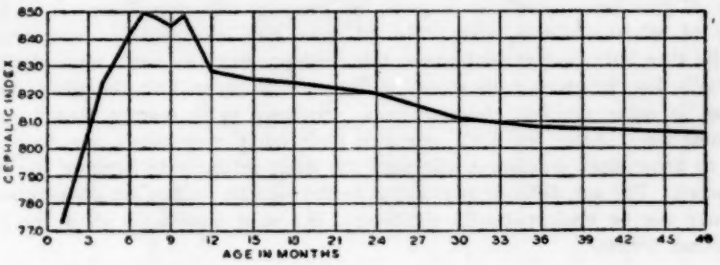

FIG. 2. CURVE OF MEANS OF THE CEPHALIC INDEX

Tschepourkowsky (11) gives mean indices for monthly intervals from months one through six for Russian infants. His data are based on measures of 709 boys and 797 girls. These indices make a steady increase from 82.3 at month one to 87.5 at month six for boys, and from 82.3 at month one to 86.05 at month four for girls. The girls' means drop slightly at months five and six (to 85.2), but there are fewer cases at these ages. Ranke (10) gives mean indices for 11 boys and 9 girls under 21 days of age. These means are 81.5 and 80.7, respectively. His mean for the next age interval, one year, is based on only 2 boys and 7 girls and is 83.9 for both sexes. His means for the later ages do not again fall as low as those given for new-borns until nine years. These data, too, show that there is an increase in cephalic index after birth. But the trend toward increasing brachycephaly is more plainly evident in Tschepourkowsky's data. This trend is closely similar (though the indices are all higher) to the trend found in the present study, toward increasing brachycephaly from birth to seven months of age. Since the Infant Growth Study sample, though small, is constant, this curve of growth through the first three years cannot be the result of chance variations due to sample selection.

SEX DIFFERENCES IN CEPHALIC INDEX

Although the sex differences in this group of sixty children are too small to be statistically significant it is interesting to note that after month eleven the mean for the boys is always higher than that for the girls. This sex difference after eleven months is in accord with the results of a number of other studies.

Gray and Ayres (7) found the boys' cephalic indices to be higher from one to eight years, after which age the girls' indices were higher. Wallis (12),

who summarized the data of a number of studies in comparison with her own, found that, as a rule, boys have higher indices than girls from two to six years, after which ages the sexes are closely similar for a while and then the boys' mean index becomes smaller than the girls'. This is not true for all racial groups, however. In some races studied the relationship fluctuates from age to age, and in others the girls remain more brachycephalic at all ages. A recent example of this latter condition is given by Fleming (6) who found, in a large group of Welsh children, that: "At all ages girls are slightly more brachycephalic than boys, and at adolescence this tendency becomes much more distinct."

Wallis has interpreted these sex differences to mean that the girls are, in this as in other physical characteristics, relatively more mature than boys of the same age. After the girls approach their adult proportions, the boys continue to grow more dolichocephalic until the adult relationship between the sexes is reached. The sex differences reported in the various studies are all very small, and may not be mathematically significant, but most studies do show the same directional trends.

If the differences found for the Infant Growth Study group *are* true differences, which follow the processes of maturation suggested by Wallis, this difference is not evidenced in a more rapid increase in index for the girls during the first seven months. The differential growth rate does not become apparent before ten months of age at the very earliest. Tschepourkowsky's data show no early sex differences either. His means for the sexes are remarkably close at all but month six.

WHAT CAUSES THE CHANGE IN CEPHALIC INDEX?

The question may be raised whether the head shape in the early months results from birth molding, or from pressure during early infancy, or is a function of innately varying rates of growth in different body parts. An answer to the first possibility is indicated in the one case of Caesarian birth in this group (Figure 3). The curve of changes with age in this child's index starts well below the average of the group and makes an even more pronounced shift from a low to a high index during the early months than is found for the group as a whole. Though one case cannot give conclusive proof, it lends weight to the hypothesis that the change is not a result of external pressure at birth. Further support of this hypothesis is to be found in the fact that, though the boys' heads, in all dimensions measured, average slightly larger than the girls' heads, and might, therefore, be more subject to pressure at birth, there is no suggestion of a sex difference in the indices during the first eight months. In ad-

dition, the children have been divided into first-born and non-first-born, eliminating twins and cases where the only previous pregnancy was not completed (Table 3). There are 26 first-born, and 28 non-first-born. The mean index of the first-born is smaller for the first four months of age, but the two means differ by only one or two points. This difference is too small to be significant.

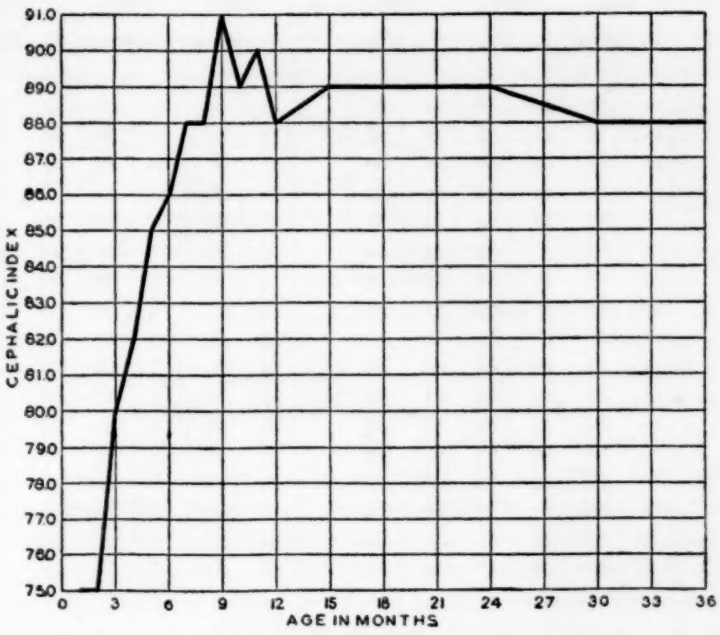

FIG. 3. CURVE OF THE CEPHALIC INDEX OF CASE 44

Boas (5) considers the possible effect of pressure on the back of the head on infants' cephalic indices, but concludes that indices of different national groups show no relation to the customary treatment of the infant in such things as swaddling, using soft feather pillows, etc. It has been possible, in the present group of children, to observe the influences of pressure by another method. Since individual children vary greatly in their activity, the inactive child might lie inert on the back of his head for many more hours than the active child, and so might become more brachycephalic. To test this supposition, the amount of change in a child's index (from the index at month one to

TABLE 3

The Mean Cephalic Index of First-Born as Compared with Non-First Born Children

	FIRST-BORN						NON-FIRST BORN					
	Boys		Girls		Total		Boys		Girls		Total	
MO.	*No.*	*Mean*	*No.*	*Mean*	*No.*	*Mean*	*No.*	*Mean*	*No.*	*Mean*	*No.*	*Mean*
1	10	.77	13	.76	23	.77	13	.77	11	.79	24	.78
2	12	.79	14	.78	26	.78	17	.79	10	.81	27	.80
3	12	.81	14	.80	26	.80	16	.81	10	.83	26	.82
4	12	.82	13	.82	25	.82	17	.83	11	.84	28	.83
5	11	.83	13	.84	24	.83	16	.82	11	.85	27	.83
6	12	.85	12	.83	24	.84	15	.85	10	.86	25	.85
7	10	.86	11	.85	21	.85	14	.84	10	.86	24	.85
8	10	.85	11	.85	21	.85	13	.85	10	.85	23	.85
9	10	.86	11	.85	21	.85	13	.84	10	.85	23	.84
10	9	.86	10	.86	19	.86	14	.84	7	.86	21	.84
11	11	.85	10	.85	21	.85	13	.83	5	.82	18	.83
12	10	.84	13	.83	23	.83	16	.83	9	.82	25	.83
15	9	.83	13	.83	22	.83	16	.82	9	.82	25	.82
18	7	.84	13	.83	20	.83	15	.82	8	.82	23	.82
24	8	.82	11	.83	19	.82	14	.83	7	.81	21	.82
30	9	.82	11	.81	20	.82	14	.82	9	.81	23	.81
36	9	.82	11	.81	20	.81	14	.81	8	.81	22	.81

the highest index reached by him) was correlated with his activity at twelve months as rated on a seven-point scale. The correlation is —.39. That is, there is apparently a slight, but definite tendency for the inactive children to change more in head shape during the early months of life. A smaller and insignificant relationship is found between amount of change in cephalic index and the children's scores in tests of "antigravity" responses (ability to hold head erect, to sit up, etc.) at six months. This correlation is —.21; that is, there is possibly a very slight tendency for children with high scores to have smaller changes in cephalic index. On the other hand, although the mean of the indices starts to decrease soon after the children are able to sit alone, there is no relationship between the age at which a child first

sat alone steadily and the age at which his index was highest: the r is .05.

It appears, then, that pressure on the back of the head does have some influence in changing a child's cephalic index. However, it is doubtful if this is the only factor influencing the early increase in brachycephaly. A third possibility is that the changes may be a function of innately varying rates of growth in different parts of the head.

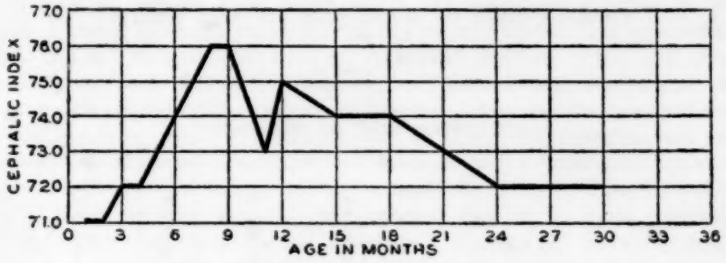

FIG. 4. CURVE OF THE CEPHALIC INDEX OF CASE 2

The indices of another child in the Infant Growth Study support this latter possibility. Case 2F (Figure 4) is a child with a definite facial asymmetry who habitually lay on one side, and cried if placed on her back. In comparison to the group she was very dolichocephalic at all ages. But in spite of the fact that she never lay on the back of her head, her index shows a steady increase from 71 at month one to 76 at month eight, and after month nine it drops again. If pressure on the head caused by lying in one position were the sole factor in changing the shape of the head, we should expect a decrease rather than an increase in the cephalic index of this child during the first eight months.

The relatively more rapid increase of the lateral dimensions during the first year has been noted previously for other measurements (3). Hip width, shoulder width and chest width, when each is compared to itself at month one, grow, during the first year, relatively more rapidly than does total length. The Weight/Length^2 index and the Hip-width/Length index both show age trends similar to that of the cephalic index, though in these two body build indices the measures of width are compared with length rather than with anterior-posterior dimensions.

Since there were no distinctly separate racial or nationality groups it was impossible to determine whether there are racial differences in the individual curves of growth. The present findings indicate that the two factors most influential in changing the shape of the head are (1) pressure on the back of the head during the early months, and (2) innate differences in rates of growth of different parts of the head.

CORRELATIONS OF HEAD LENGTH AND WIDTH

TABLE 4

Intercorrelations of Measures

	MONTH 1	MONTH 6	MONTH 12	MONTH 24	MONTH 36
Head Width by Head Circumference....	.58	.61	.68	.70	.68
Head Width by Weight.....	.49	.52	.59	.48	.55
Head Width by Length.....	.39	.61	.57	.59	.47
Head Width by Head Length.....	.25	.02	.26	.27	.22
Head Length by Head Circumference...	.82	.65	.70	.55	.67
Head Length by Weight.....	.50	.34	.60	.40	.51
Head Length by Length.....	.48	.34	.58	.46	.40

The two diameters of which the cephalic index is composed have been correlated with each other, and with head circumference, total length and weight. In the previous study (3), when any one of the body measures was compared with any other, the correlations were found to be of the order of .50 or higher. An inspection of Table 4 shows that the same tendency holds for a relationship in size of the head diameters to other body measures. But when head width is compared with head length the correlations are very low — of the order of .20. These are the only two measurements, of those which have been correlated on these children, that do not show a definite relationship between their relative magnitudes. Whether there is any significance in this deviation from the general tendency for body dimensions to correspond, it is difficult to say. Since the two head diameters are among the most reliable measurements, we may assume

that the lack of relationship between them is not caused merely by errors of measurement. The low association may possibly be the result of environmental influences on a few of the cases: differing amounts of birth molding in the first month, and pressure on the back of the head of inactive babies at later months might serve to distort the two diameters of a few children sufficiently to reduce the correlations almost to zero.

Correlations between head length and width have been reported in several studies. Fleming (6) correlated measurements of over six thousand observations of Welsh children between the ages of three and eighteen years, and obtained, partialling out age, correlations between head breadth and head length of .29 for boys and .36 for girls. Her data, however, show equally low relationships (r's ranging from .25 to .35) between each of these head diameters and stature. This disparity between her results and ours in these latter correlations may be due to differences in sample, and in treatment of the data. Fleming's data are obtained from different age and racial groups, and age is made constant statistically rather than by actual age groupings. Wallis (12) correlated measurements of diameters of groups of crania, and found that the r's between head breadth and length varied, in different racial groups, from .62 to —.04, with high r's to be found in groups with small standard deviations of the cephalic index, and low r's occurring where the standard deviations are large. Most of the correlations are of approximately the same magnitude as those found in the present study, though the indices of the infants tend to have larger standard deviations. The greater spread of the infants' indices may be due both to greater racial heterogeneity of the sample, and to the variation caused by rapid growth changes in the indices of some of the children at these early ages. The S. D.'s are especially large from months three to eleven, when they are affected by wide individual differences in tendency to change with age.

CONSISTENCY OF CHANGES IN CEPHALIC INDEX

We have seen that, for the group, the cephalic index changes with growth. It will be of interest, then, to determine whether these changes are to be found in all individual cases, and whether the children tend to maintain their relative position in the group. It is clear that, on the average, the children are more brachycephalic from seven to nine months than they are before or after this age; but do those who are most brachycephalic at this age tend, also, to be most brachycephalic at other ages? One way of determining this is to compute correlations between the indices obtained at varying ages. Some of the r's are given in table 5, showing the consistency of the index between different ages. When the age interval between measurements is relatively short, the correlation tends to be high, especially after twelve months.

TABLE 5

Self Correlations Showing Consistency of Relative Head Shape

		MONTHS								
		3	6	12	18	24	30	36	48	60
Months	1	.78	.69	...	.71	.51	...	.51	...	.55
	3		.82	...	...	.66	...	.72	...	...
	6			.82	...	.80	...	.78	...	.80
	12				.94	.91	...	.88	...	.89
	18					.94	...	.92	...	...
	24						.94	.86	...	.87
	30							.95	...	...
	36								.93	.95
	48									.96

But when the interval is increased the correlations drop, although there is still a definitely positive relationship over the longest interval studied here, as shown by the correlation of .55 between the measurements at months one and sixty. It is not until twelve months, when the index has reached a point after which the change is very gradual, that the correlations show a very high consistency, or stability, in head shape.

Individual children differ in rate of growth, in the extent to which the index changes, and in the age at which the highest index is reached. These differences are shown most clearly in the individual curves of growth of which figures 3 and 4 are widely different samples. The individual curves also explain the larger S. D.'s of the cephalic index during the first year (Table 2), and the lower consistency of indices under one year, when two ages are correlated (Table 5).

When the individual curves are plotted for each child the curves are found to vary widely in their tendency to change, ranging from the curve of one child whose increment from the lowest to the highest index is only two points to one whose increment is 16 points, with the majority exhibiting curves similar to the mean of the group (Figure 2). The curves may be roughly classified according to (1) the amount of increase after month one; (2) the amount of decrease at

later ages; and (3) the ages at which the highest indices occur. The first classification has been used in showing the significance of environmental factors on head shape. The two latter classifications have, as yet, yielded no significant relationships to other factors.

The extent to which the head shape is related to other characteristics of the individual has been studied in this group for a few characters. It seemed possible that cephalic index is related to body build as manifested in some of the indices of build which we have computed (3). This appeared all the more likely, as the curves of the group averages of the cephalic index and the Weight/Length^2 index have similar trends of growth. We see, however, from the correlations in Table 6 that, for individual children, at no age is the size of the cephalic index related to that of the Weight/Length^2 index. Neither is there any relationship between cephalic index and the Stem-length/Length index. Within this sample, brachycephalic infants are not more likely to be of pyknic build; nor are the dolichocephalic children more often leptosomes.

Table 7 shows that in this group of children there is no significant relation between the shape of the head and relative maturity

TABLE 6

Correlations of Cephalic Index with Indices of Body Build

MONTH	W/L^3		SL/L	
	No.	r	No.	r
1	50	—.02	50	+.24
3	58	+.03		
5			55	—.19
6	56	+.12		
9	51	+.09		
12	55	+.06	55	+.09
15	52	—.02		
18	46	—.25		
24	41	+.08	41	—.14
36	49	—.01	49	—.17

TABLE 7

Correlations between Cephalic Index and Performance

MONTH	MENTAL TEST SCORES		MOTOR TEST SCORES	
	n	*r*	*n*	*r*
1 ..	50	.34	50	.12
2 ..	58	.09	58	—.06
3 ..	58	.39	59	.15
6 ..	55	.12	56	.05
12 ..	53	—.03	54	—.06
24 ..	42	.04	42	.06
36 ..	49	—.22	49	.08
60 ..	46	—.14		

of performance in either mental or motor test scores.[1] The slight tendency toward positive *r*'s with the mental test scores at the ages when the index is increasing, and negative *r*'s when the index is decreasing may possibly be more than a chance factor. If so, one might say that the more rapidly maturing child tends to mature more rapidly both in head form and in performance on mental tests. The low correlations, however, make such a conclusion extremely tentative.

SUMMARY

Head width and head length may be measured reliably in children as young as one month of age.

The cephalic index, on the average, increases rapidly from one through seven months, remains at an approximately constant level until ten months, and then decreases — very slowly after twelve months of age. Individual curves show that the children vary in the extent to which they become more brachycephalic during the first year, but all of the children in this group exhibit the tendency to some extent.

[1] The tests used are the California First-Year Mental scale (1) and the Infant scale of Motor Development (2), both of which were standardized on this same group of children; and the California Pre-school Mental Scale by A. S. Jaffa (9).

The less active of these children who would, accordingly, spend more time lying on their backs, tend to have greater increases in cephalic index than do the more active children. But the relationship is not high. There is some evidence that the change is due, in part, to physiologically disparate rates of growth in the two head dimensions. There appears to be no relationship between head shape and nationality, or conditions of birth.

The standard deviations of the indices are larger during the first year when growth changes are most rapid, and when there are large individual differences in the extent to which the index changes with growth.

There is very little association (r of .20) between the two head diameters in the same individual. This is a radical departure from the correlations of .50 or above between other body dimensions for the same children and may be due to external pressure which affects the cephalic proportions of some children more than others.

Correlations between cephalic indices of the same children at different ages are fairly consistent at all ages measured, with high relationships (a) when the age interval is small, and (b) after the age of twelve months, when growth changes are small.

The cephalic index is not related to the Weight/Length^2 or Stem-length/Length indices of body build. Neither has the cephalic index any significant relationship to ability in tests of mental performance or motor coordination.

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HOMOGAMY AND INFERTILITY

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RECORDS of a consecutive series of 107 infertile married couples who had been thoroughly studied for diagnostic purposes at the Evans Memorial (Boston, Massachusetts) afforded an excellent opportunity to investigate the possible relations existing between homogamy and infertility.

The routine program for this study of sterility has been described by Rowe (9), and a preliminary discussion of the constitutional factors involved was published by Meaker in 1929 (4).

I am grateful to the late Dr. A. W. Rowe and to the other members of the Evans Memorial for their kindness in placing their records at our disposal; and to Miss Edith Fishman for indispensable technical assistance.

AGE

Homogamy correlations in age are subject to the difficulty that they may have age heterogeneity as a component; thus a coefficient derived from a general population will inevitably be larger than one from a population of pairs recently married.

The order of the former is derivable from the figures of Pearson and Heron (7) on the British census and those of Willoughby (11) on Boas' immigrant population — .92 and .84 respectively; fairly homogeneous populations have been studied by Lutz (2), Carter (1), Schiller (10), and Outhit (5), and these yield figures of .76, .75, .69, and .79 respectively. The most representative value of the latter group is probably Lutz' .76, and the lowest Schiller's .69.

The median age for husbands in the present series is about 33, and that of the wives about 30, and there are few cases of either sex above 40 years of age. Thus this may be considered a fairly homogeneous population, and thus expected to have a relatively low coefficient; it has one, however, of .51 $\pm$ .05, which is some twenty points lower than the lowest previously found, and in consequence is an outstanding characteristic of the infertile group. The variation due to nationality

shown in Willoughby's study (11) — .82 to .89, with one small group at .66 — gives no ground for supposing that this result may be influenced by any anomalous racial composition.

STATURE

This simple and satisfactory measure yields means of 170.9 and 159.5 cm. for the males and females respectively of the infertile series, with corresponding standard deviations of 3.5 and 3.2 cm. The mean for the female is anomalously low, when compared with that given by Martin (3) for Europeans.

The homogamy coefficient in stature for the infertile series is .63 ± .04, the highest figure yet found for a somatic character in man. A check series composed of Husband A vs. Wife B, Husband B vs. Wife C, etc., yielded a coefficient of .01, thus ruling out the possibility of general intercorrelation throughout the series. Other presumably comparable coefficients (11, 6, 8, 10) range from .08 to .33, with an average value of the order of .2; they appear to be somewhat subject to socio-economic influences, but very slightly to racial or national ones. Thus there seems to be nothing immediately in view to invalidate the hypothesis of some sort of organic relationship between the infertility and the exceptionally high homogamy.

Physiological Measures

On account of the difficulties inherent in basal metabolism determinations, a subseries of 49 pairs were distinguished in which the data were regarded as fairly stably determined; the homogamy coefficient for this subseries was .33, and that for the total series of 107 pairs was .23. Comparable data for fertile pairs are lacking.

For per cent deviation from prediction in lung volume, a coefficient of .22 was found, and for total blood nitrogen .47; the latter determination in particular is subject to an error due to the extreme variability of blood composition.

A study was made of variations in the homogamy coefficient for height as a function of the incidence of endocrinopathy, careful diagnosis of which was made in connection with the infertility. In 26 pairs in which one member had a thyroid disturbance (most typically insufficiency) the coefficient was .46; in 64 pairs one or both members of which suffered from pituitary dysfunction the coefficient was .58;

in 26 pairs characterized by ovarian insufficiency it was .55; and in 19 pairs without endocrine etiology it was .82.

Other Somatic Measures

Homogamy coefficients of appreciable size were obtained for area (.41), trunk length (.40), and weight (.30) from this series; and insignificant coefficients were found for chest circumference (.14) and hip circumference (.07). All these except trunk length can be regarded as depressed by the error due to differential fat accretion with age and sex. Their significance for infertility is unknown, as there are no comparable figures for the fertile.

The Effects of Heightened Fertility

An attempt was made to ascertain the correspondence between fertility and homogamy by subdividing the Boas populations investigated by Willoughby (11) so as to secure smaller populations of exceptional fertility (more than three children, or in one case where this would have given inadequate numbers, more than two).

The age correlations in these subpopulations are slightly depressed (.89 to .88, .83 to .71, and .83 to .76 or .78); this result apparently follows from the fact that a population with more than three children is necessarily one more homogeneous in age than an unlimited population. The somatic correlations are essentially unaffected in the case of two of the racial groups considered, but significantly raised in that of the Italians (.12 to .19 for the average of four measurements and two indexes).

It will be recalled that there are in the literature some occasional references to the correspondence of homogamy with fertility, but that they are inconsistent as to direction.

SUMMARY

In a study of a series of 107 infertile couples at a sterility clinic certain alterations of normal homogamy coefficients were established which appear to point to possible etiological significance:

(1) The homogamy in age is conspicuously depressed below that of the general population.

(2) The homogamy in stature is conspicuously elevated above that of the general population.

(3) There are marked variations in stature homogamy corresponding to type of endocrinopathy, increase being in the following order: thyroid, pituitary, non-endocrine.

(4) Re-examination of the data of another study yields a result suggesting that — in contrast with (2) — in Italians a portion of the population selected for demonstrated fertility may be more homogamous than the general population; this result is not found in other nationality groups.

These findings, taken in conjunction with those already in the literature, suggest that the influence of homogamy upon fertility is real but specific, acting in different directions for different characters and to different degrees in different groups and characters; which, in turn, suggests that more comprehensive mechanisms may be discovered of which both homogamy and fertility are functions.

Distributions and homogamy coefficients for physiological characters not heretofore so analyzed are presented in an appendix.

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APPENDIX

TABLE 1

Age at Time of Examination

	20	22	24	26	28	30	32	34	36	38	40	42
A												
m		1	2	7	11	16	19	17	14	8	4	4
f	1	5	15	14	17	22	10	13	4	2	2	

	44	46	48	50	N	M	σ	V	d_M/σ_d	d_σ/σ_d
m	3			1	107	33.66	2.45	7.28	11.83	0.56
f	2				107	29.80	2.32	7.79		

TABLE 2

Distribution of Height in Centimeters

	146	148	150	152	154	156	158	160	162	164	166	168	170
Ht													
m					2		1	8	7	7	10	16	11
f	2	4	8	7	9	16	13	15	6	8	2	11	3

	172	174	176	178	180	182	184	186	188	190
m	10	11	10	3	3	2	2	2	1	1
f	2		1							

	N	M	σ	V	d_M/σ_d	d_σ/σ_d
m	107	170.9	3.5	2.05	24.87	1.24
f	107	159.5	3.2	2.01		

TABLE 3

Distribution of Measurements of Trunk, Chest, Hips in Centimeters

T	78	80	82	84	86	88	90	92	94	96	98					
m		1		5	15	25	25	25	4	6	1					
f	3	17	19	16	30	10	10	1		1						
			N		M		σ		V		d_M/σ_d		d_σ/σ_d			
m			107		90.52		1.56		1.72		29.23		0.89			
f			107		85.37		1.70		1.99							
C	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	
m							5	7	17	19	19	20	5	7	5	
f	1	1	15	23	20	21	10	7	4	1	3					
	105	108	111		N		M		σ		V		d_M/σ_d		d_σ/σ_d	
m					107		91.60		2.18		2.38		57.10		0.07	
f			1		107		74.62		2.17		2.91					
Hp	75	80	85	90	95	100	105	110	115	120	125	130				
m	2	3	19	35	30	13	2	3								
f	1	4	24	36	24	10	4	3				1				
			N		M		σ		V		d_M/σ_d		d_σ/σ_d			
m			107		90.53		1.3		1.44		8.14		1.47			
f			107		94.15		1.5		1.59							

TABLE 4

Distribution of "All" and "Sure" Metabolic Rates

RM	−35	−30	−25	−20	−15	−10	−5	0	+5	+10	+15
All m	3	4	10	23	30	18	9	5	2		
f		2	4	14	20	29	19	11	4	3	
Sure m	2	3	4	11	9	10	7	1	1	1	
f		1	5	8	9	7	11	5	1	1	
	+20	+25	N		M		σ		V	d_M/σ_d	d_σ/σ_d
All m			107		−12.98		1.81		13.94	0.29	1.73
f		1	107		−13.16		1.78		13.53		
Sure m			49		−7.76		1.88		24.23	2.86	0.94
f		1	49		−8.88		2.00		22.52		

POPULATION GROWTH DUE TO IMMIGRATION AND NATURAL INCREASE

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I. THE LOGISTIC CURVE

IT HAS been known for some years that the logistic

$$(1) \qquad p = \frac{U}{1 + e^{a(t-t_0)}}$$

gives an excellent fit to the United States population. p is the population, U its upper limit of growth, t is time and a and t_0 are constants. It has the differential equation

$$(2) \qquad \frac{1}{p}\frac{dp}{dt} = k(U-p)$$

Indeed, the 1930 population of the United States came within less than ⅓ of 1 per cent of the forecast from the Pearl-Reed curve, fitted to data through 1910. The more careful determination of Hotelling[1] leading to the equation

$$(3) \qquad 1000 \cdot \frac{1}{p}\frac{dp}{dt} = 31.239 - 0.15949p$$

indicated a 1930 population of 121,000,000 as against a census count of 122,775,000 on April 1, 1930.

A more generalized form

$$(4) \qquad p = \frac{U_1}{1 + e^{m(t-t}} + \frac{U_2}{1 + e^{n(t-t_2)}} + C$$

fits the observed populations of Germany and Algeria.[2]

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[1] Hotelling, Harold, Differential Equations and Population Growth, *Journal of the American Statistical Association*, Sept. 1927, p. 283

[2] Raymond Pearl, The Biology of Population Growth, Studies in Human Biology

2. NON-LOGISTIC FACTORS IN U. S. POPULATION GROWTH

Now, while these fits are undeniably good, certain assumptions in the logistic theory appear unreasonable. For one thing, the Pearl theory assumes a fixed upper limit *U*. This is difficult to accept, because (a) the physical conditions determining the upper limit of population growth in the United States have certainly undergone a change during the last century, and (b) so much of the U. S. population growth is due to immigration, a factor not taken account of by the theory.

(A) In the case of Pearl's experimental populations of *Drosophila,* the glass bottle and the food supply set the upper limit and these remained constant during the experiment. But in the early days of the Republic the "bottle" was about 500,000 square miles between the Appalachians and the seacoast, and in this was growing an agricultural and handicraft economy without means of transportation. With the building of the canals and roads, the sides of the "bottle" were slowly pushed back, and by about 1840 the frontier line was at the Mississippi and the Great Lakes. After the Civil War and the great railroad development, the "bottle" was expanded to the full area of the Continental United States.

There was more than mere physical growth. A century of inventions made it possible for people to live in undreamed of comfort at a density of tens of thousands to the square mile.

Lotka[3] feels this difficulty and suggests that "It is true that, in [the growth of certain human populations] they have carried along with them a complicated industrial system or group, comprising both living and non-living elements. We may, however, look upon the number of the human population itself as a sort of single index or measure of the growth of the group as a whole."

(B) The total net immigration since the founding of the American Colonies is probably over 30,000,000, or one-quarter of the present population. Its contribution to the population has been anything but logistic. At first, immigrants were very few, partly because of the dangers of the transatlantic voyage. Regular sailing packets were not established till the 1820's and the first steamship crossed the Atlantic in 1838. The Irish potato famine of 1845 started the first of the great immigration waves.

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[3] A. J. Lotka, Physical Biology, p. 64

TABLE 1

Population
(In Thousands)

YEAR	POPULATION AS REPORTED a/	POPULATION ADJUSTED b/	Δ POPULATION d/	NATURAL INCREASE		IMMIGRATION		
				By Decades (3)-(6)	Smoothed Decadian Rate	By Decades	Cumulated	Smoothed Decadian Rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1650	52							
1660	85							
1670	114							
1680	156							
1690	214							
1700	275							
1710	358							
1720	474							
1730	655	655						
1740	889	890	235					
1750	1207	1210	320					
1760	1610	1615	405					
1770	2205	2215	600					
1780	2781	2801	586	566		20e/	160	
1790	3929	3964	1163	1123	1241	40e/	200	45.7
1800	5308	5363	1399	1349	1575	50e/	250	56.1
1810	7240	7270	1907	1845	2063	62	312	63.2
1820	9638	9673	2403	2332	2718	71	383	66.9
1830	12866	12921	3248	3125	3420	123	506	235
1840	17069	17154	4233	3740	4181	493	999	892
1850	23192	23260	6106	4686	5209	1420	2419	2106
1860	31443	31502	8242	5684	5976	2558	4977	2369
1870	39818	39915	8413	6339	7102	2074	7051	2088
1880	50156	50262	10347	7767	7788	2580	9631	3920
1890	62948	63056	12794	7830	8557	4964	14595	4312
1900	75995	76129	13073	9384	9703*	3689	18284	5195
1910	91972	92422c/	16293	10050	10831*	6243	24527	4354
1920	105711	106424c/	14002	11777	13149*	2225	26752	2723
1930	122775	123191	16767	13432	11221	3335	30087	1760
1940	131775			8630				

TABLE 1 — (*Continued*)

YEAR	POPULATION AS REPORTED a/	POPULATION ADJUSTED b/	Δ POPULATION d/	NATURAL INCREASE By Decades (3)-(6)	NATURAL INCREASE Smoothed Decadian Rate	IMMIGRATION By Decades	IMMIGRATION Cumulated	IMMIGRATION Smoothed Decadian Rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950				8000				
1900♯	75995	76129	13073	9384	9652*	3689	18284	5153
1910♯	91972	92422	16293	10050	11234*	6243	24527	4690
1920♯	105711	107532	15110	12381	13149*	2729	27256	2723
1930♯	122775	123191	15659	12828	10820	2831	30087	1425
1940	131775	131821	8630	8630		0		
1950				8000				

a/ Thompson, Warren S. and Whelpton, P. K. *Population Trends in the United States*, McGraw-Hill Book Co. 1933, p. 1

b/ Adjusted for (a) non-reported areas (1790-1840); (b) July 1 population

c/ W. I. King, *The National Income and Its Purchasing Power*

d/ Decennial increase calculated from Col. (2)

e/ Thompson and Whelpton, p. 301

♯ Figures for these years are adjusted for effects of war on natural increase and immigration

* Natural increase in these years 1055, 1389 and 1108, respectively

Figures for 1940 and 1950 estimated in order to calculate interpolated values for 1930

The next great wave, after the Civil War, was due to the attraction of the New West. See chapters on immigration in any good economic history of the United States.

3. DATA

The first column of Table 1 gives the reported Census counts, the 1870 count being adjusted upward for under-enumeration. The second column is (a) adjusted for population in areas not covered by U. S. Census during 1790-1840. (This was done rather crudely by extrapolating available data backwards); (b) adjusted to July 1 (the date of

the decennial Census varies). Column 3 shows the decadian increase, made up of natural increase (column 4) and net immigration (column 6). Early immigration data are very unsatisfactory, and so is cumulated immigration (column 7). "Franklin, when he estimated in 1755 that there were 'near a million souls' in the colonies, thought that scarce 80,000 had been brought over by sea."[4]

The natural increase and immigration were interpolated by the formula[5]

$$u'(0) = \frac{1}{12}\left[-u_{-\frac{3}{2}} + 7u_{-\frac{1}{2}} + 7u_{\frac{1}{2}} - u_{\frac{3}{2}}\right]$$

Thus the decadian rate of natural increase at 1790 is $\frac{1}{12}(-566 + 7 \times 1123 + 7 \times 1349 - 1845)$

4. DIFFERENTIAL EQUATIONS FOR NATURAL INCREASE AND IMMIGRATION

Let

y = population derived from natural increase, i. e. all children born in the country in excess of deaths

z = population derived from immigration; cumulative net immigration. Children of immigrants in excess of decedents are counted in the y-population, inasmuch as they are natural increase.

Then write

$$(5) \quad dy/dt = k(y + z)\ [U - y - z]$$

This is the differential equation of the ordinary logistic curve, where the population p is given by $(y + z)$, and increase from births appears

[4] E. L. Bogart, Economic History of the American People.

[5] This formula gives the center ordinate of a cubic $u'(x)$ fitted so that

$\int_{-2}^{-1} u'dx = \Sigma u$ in interval $(-2, -1)$

$\int_{-1}^{0} u'dx = \Sigma u$ in interval $(-1, 0)$

$\int_{0}^{1} u'dx = \Sigma u$ in interval $(0, 1)$

$\int_{1}^{2} u'dx = \Sigma u$ in interval $(1, 2)$

in the left-hand side instead of natural increase. The natural increase rate per head is given by

$$(6) \qquad \frac{1}{y+z} \cdot \frac{dy}{dt} = k_1[U - (y+z)] = k_1[U - p]$$

The differential equation for net immigration is harder to select, and none appears wholly satisfactory. The determinants of immigration are

(r_2) opportunities in the new country compared to

(r_1) opportunities in the old and to

(c) cost and discomforts of the voyage and

(f) physical facilities for transport

We can, not without some misgivings, take z itself as a measure of the carrying capacity of the transportation equipment; and, neglecting the other factors for the moment, write

$$(7) \qquad \frac{dz}{dt} = k_2 z$$

which states that, in the absence of inhibiting factors, immigration tends to grow according to the exponential law. The full equation might be given by

$$(8) \qquad \frac{dz}{dt} = k_2 z(r_2 - r_1 - c)$$

We may call () the *attractiveness factor,* and if we assume that this is proportional to the as-yet-unexploited opportunities for population growth, the "vacuum" between $(y + z)$ and U, (8) may be written as

$$(9) \qquad \frac{dz}{dt} = k_2 z(U - y - z)$$

and the population growth of a country will be given by the simultaneous differential equations

$$(10) \qquad \frac{1}{y+z} \cdot \frac{dy}{dt} = k_1[U - p], \ (p = y + z)$$

$$\frac{1}{z} \cdot \frac{dz}{dt} = k_2[U - p].$$

These equations state that the natural increase per head and the immigration per cumulated immigration are both linear functions of the attained population. The former is especially important because it is the equation required by the logistic theory. Pearl neglected the immigration effect and used the equation (2).

5. AGREEMENT WITH OBSERVATIONS

Natural increase per decade per head is shown in Column (a) of Table 2, and the graph. Decidedly, it is not linear, and hence the United States population growth does not verify the logistic theory. As the curve is convex to the p-axis, it appears as if the upper limit towards which the population was "aiming" at the time has steadily risen. For example, if we fit a straight line to the 4 points for 1790, 1800, 1810 and 1820, we find it intersects the p-axis at 64,000,000. Similarly a straight line fitted to the populations for 1820, 1830, 1840 and 1850 indicates an upper limit of 76,000,000. The upper limit indicated from the years 1890—1920 was 474,000,000 and that calculated from the period 1900—1930 indicates a potential population of 247,000,000.

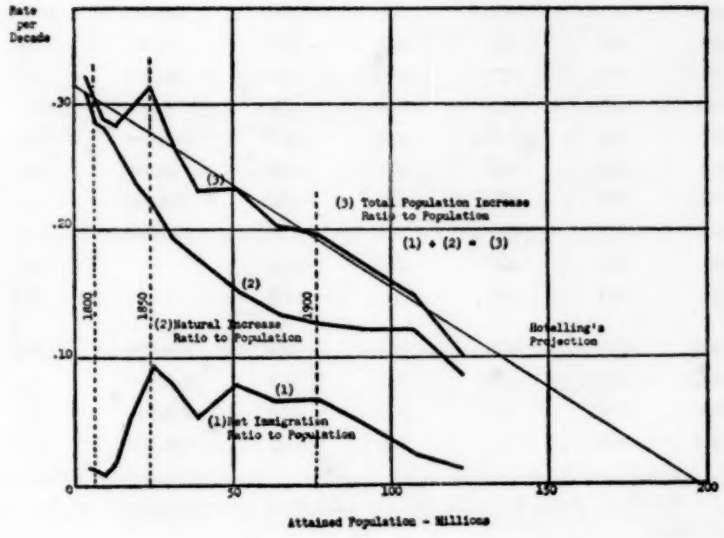

CHART I

Now the interesting thing about these indicated potential populations is not so much their failure to remain constant with the passage of time, as required by the logistic hypothesis, but their general agreement with historical analysis. That analysis shows a constant upward shift of the potential due to new inventions and discoveries. It is im-

TABLE 2

Rates of Natural Increase and Immigration

YEAR	RATE OF NATURAL INCREASE (5)/(2)*	IMMIGRATION (8)/(2)*	SUM (a) + (b)	(8)/(7)*	UPPER LIMIT	(1) + (4)*
	(a)	(b)	(c)	(d)	(e)	(f)
1790	.312	.012	.324	.228		.540
1800	.294	.010	.304	.224		.518
1810	.284	.009	.293	.202		.486
1820	.281	.007	.288	.175	64,000	.456
1830	.265	.018	.283	.465	87,000	.730
1840	.244	.052	.296	.892	75,000	1.136
1850	.224	.091	.315	.871	76,000	1.095
1860	.190	.075	.265	.476	80,000	.666
1870	.178	.052	.230	.296	97,000	.474
1880	.155	.078	.233	.407	113,000	.562
1890	.136	.068	.204	.296	140,000	.432
1900	.127	.068	.195	.284	164,000	.411
1910	.117	.047	.164	.178	246,000	.295
1920	.123	.026	.149	.102		.225
1930	.091	.014	.103	.058		.149
1900♯	.127	.068	.195	.282	164,000	.409
1910♯	.122	.051	.173	.191	246,000	.313
1920♯	.122	.025	.147	.100	474,000	.222
1930♯	.088	.012	.100	.047	247,000	.135

♯ Figures for these years are adjusted for effects of war on natural increase and immigration

* Figures in parentheses refer to numbers of columns in Table 1

possible to read in economic history how population movements were conditioned by the geographical knowledge, the highways and the state of the arts of the time, how births and deaths were affected by the contemporaneous state of medicine and sanitary engineering and how large cities were made possible by the development of agricultural machinery, high speed transportation, electric power, steel frame buildings, refrigeration, and canning, and believe that in earlier periods the population was growing towards an upper limit governed by physical factors and inventions which were not to come into being for fifty years. It is much more natural to believe that the population at any one moment is growing towards the upper limit imposed by the existing physical factors. In this view the observed population curve consists of a number of short logistic arcs a_1, a_2, a_3, a_4, etc. growing towards the successively higher limits U_1, U_2, U_3, U_4, etc. (See Chart 2), and the eventual upper limit is indeterminate, and cannot be inferred from past observations.

It may be that human populations can indeed be represented by logistic curves. New inventions and discoveries only become fully effective over a span of years, only take effect gradually. This operates to smooth

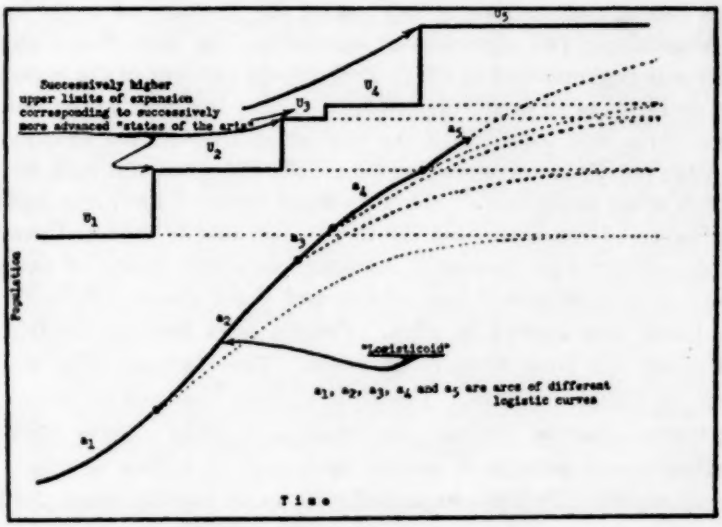

CHART 2

out both the stair-case-like upper limit in chart 2 and the junctions of the individual logistic arcs. The observations of chart 2, although arising from a non-logistic process, can be fitted quite well by a single logistic.

6. LOGISTIC FORM OF U. S. POPULATION DUE TO TIMING OF IMMIGRATION WAVES

Net immigration as a fraction of attained population is shown in Chart 1. It came in in a series of waves, and takes a form generally concave to the p-axis. This concave curve fits nicely into the convex curve for natural increase, and just fills out the hollow enough so as to produce the straight-line relationship observed by population students. The ratio of immigration to cumulative immigration is shown in Table 2. It is obviously non-linear, and hence differential equation (9) does not fit. If the invention of the iron ship had been delayed 20 years, the logistic curve would probably have fitted very poorly.

7. FACTORS DETERMINING THE UPPER LIMIT

Some of these are: (a) *The frontier,* which in colonial times was at the foot of the Appalachians. In 1840 it reached the Mississippi and the Great Lakes, and by 1860 it had passed the first tier of states beyond the Mississippi; (b) *Agricultural machinery.* The McCormick-Deering reaper was demonstrated in 1831. Probably 90 per cent of the population lived on farms or in small rural villages. Today less than 40 per cent live on the farm, and one-fifth of the population lives in five metropolitan districts; (c) *Transportation facilities.* The Clermont was built in 1807. In 1816 steam navigation on the Mississippi began. "The great economic significance of the steamboat lay in the fact that it rendered available at once, without any expense of construction, a vast system of navigable waters, which permitted easy, cheap and rapid transportation." The Erie Canal was opened in 1825. Freight rates between Buffalo and New York fell from $100 to $5 a ton. The National Pike was extended to Illinois by 1838. The B. & O. first operated in 1830. The first transcontinental railroad was finished in 1869. There were half a million motor vehicles in use in 1910, and 25 million in 1930; (d) *Energy supply.* This has expanded with great rapidity since the Civil War. In 1871-75 it averaged 1520 trillion BTU per year; in 1929, 26,534 trillion BTU. The horsepower of central electric stations grew

from 2 million in 1902 to 36 million in 1927; (e) *Land policy.* After the Civil War the homestead laws opened up the great territory between the Missouri and the Far West. A rapid influx of population took place; (f) *Food preservation.* Of very great importance were the many inventions making it possible for city populations of several millions to live at a distance from the source of food supply: rapid transport, refrigeration and canning.

8. IMMIGRATION

Steam and iron effected such an increase in the safety and carrying capacity, and decrease in the cost, of the transatlantic service that he would be hardy indeed who asserted that immigration followed any analytic formula, logistic or otherwise.

The logistic theory would still be acceptable if it can be shown that $\frac{dy}{dt}$ and $\frac{dz}{dt}$ are causally interrelated in such a way that their sum is subject to the condition that

$$(11) \qquad \frac{dy}{dt} + \frac{dz}{dt} = k(y+z)\ (U-y-z).$$

This is equation (2). It sets a "quota" for new additions to the population, to which immigration and natural increase have to adjust themselves.

(a) But it is clear that immigration cannot be affected by the birthrate of the country of destination. The sharp bulge in immigration in 1840 — 1850 — 1860 was not due to an emergency call for immigrants to offset the deficit in births below the straight-line relationship. The causes of that wave lie outside the United States: application of steam power to ships (which shortened the period of travel from 4 to 8 weeks to 15 days), use of iron (which gave strength and safety, and made large size and hence low cost possible), and the Irish potato famine of 1845.

(b) Nor are births much affected by immigration, or a mere alternative for it. Authorities now generally reject this theory which was advanced in the nineteenth century. Besides, if so, minor saw-teeth ought to appear in $\frac{1}{p}\frac{dy}{dt}$ negatively correlated with the pronounced saw-teeth in $\frac{1}{p}\frac{dz}{dt}$.

9. POPULATION FORECASTS

Since the writer contends that U is not determined by present and past population factors, (but by unknown influences yet to appear), values of U calculated from the observations are only suggestive, and the standard error is unknown.[6]

However, even revolutionary inventions take effect but slowly, and short time forecasts by the Pearl-Reed curve are entirely feasible — say over a 10 or 15 year period. A large error in U will cause only a small error in short-term forecasts.

The differential equations here encountered will be discussed in a paper by the writer and L. J. Paradiso, now in preparation.

CONCLUSIONS

1. The apparent verification for the United States of the logistic theory of linear relationship between the (logarithmic) rate of growth and the attained population is due to a historical accident — that the immigration tide arrived when it did, and in such a way as to "fill in" the obviously curvilinear relationship for natural increase.

2. The generalized theory, to take account of immigration, is not verified either (equations 10). Natural increase and immigration growth ratios are not linear functions of attained United States population.

3. The observed course of the population can be fitted by a succession of Pearl-Reed arcs, joined, each directed towards a different upper limit.

4. Economic-historical analysis indicates that the potential upper limit of population has increased with time, due to territorial expansion and invention, and moreover the observed relationship of the rate of natural increase, its convexity to the x-axis, is consistent with such a shifting upper limit.

5. The limit towards which the population is growing at any instant is probably a function of the contemporaneous "state of the

[6] The results obtained by Henry Schultz, *The Standard Error of a Forecast from a Curve*, Journal of the American Statistical Association, June, 1930, p. 139, of course apply only so long as underlying physical factors remain constant.

arts" and geographic discoveries and there is no reason for supposing that it varies in accordance with any simple mathematical law.

6. And hence future upper limits, being determined by yet-to-exist unknown conditions, are indeterminate, and are not solely a function of the past course of population growth.

7. Hence, although short forecasts can legitimately be made by the Pearl-Reed technique, long-time forecasts are subject to an unknown and probably large error of estimate.

STUDIES ON CONSTITUTION, III
SOMATOLOGICAL DIFFERENCES ASSOCIATED WITH DISEASES OF THE HEART IN WHITE FEMALES*

BY ANTONIO CIOCCO

THE purpose of this paper is to present some statistical data relative to the somatic constitution of white women with heart disease. Pearl and Ciocco (16) have recently published the results of an analogous study on white men, and this, in part, may be regarded as a sequel to that work.

THE MATERIAL AND THE PROBLEM

This study is based on the records of clinical and anthropometric observations made under the direction of Raymond Pearl at the Institute for Biological Research (now the Department of Biology of the School of Hygiene and Public Health) of the Johns Hopkins University. The history of the organization and the technique used have been amply described (17), and need not be repeated here.

According to the results of the clinical examination made at the Johns Hopkins Hospital, the material is divided into two groups. In one group are those patients *who at the time of examination* gave no clinical evidence of cardiac disease. These are the non-cardiacs. In the other group are those *who at the time* gave clinical manifestations of heart disease, mild or grave as the case might be. These are the cardiacs.

The basic problem with which this study is concerned is: What, if any, significant somatological differences are there between the cardiacs and the non-cardiacs in this material? The object of this study is thus evidently purely descriptive, but, it is hoped, it will aid in

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establishing a solid foundation for a true science of human constitution. For the purpose in mind and in terms of the general biological aspect of the problem the author has not segregated known or presumed etiological factors, assuming that it was equally possible for each of the patients to be subjected to them. Therefore, a clinically recognizable lesion of the heart from whatever cause is regarded as an objective expression of the biological weakness or impairment of this organ. Actually though by selecting for this study only individuals above a certain age limit it has resulted that the majority of the patients are those affected by degenerative forms of heart disease.

AGE DISTRIBUTION

The incidence of heart disease, taking all forms together, increases with age. Therefore, if all the women in this collection had been used, the group of cardiacs would be much older than the non-cardiacs. To eliminate this disparity in age, which in some cases has influence on the somatic constitution of the individual, this study is confined to women falling between the ages of 40 and 69 years inclusive.

The total women in the two groups so limited is 163. Of these 126 are cardiacs and 37 non-cardiacs. The biometric constants for age are as follows:

	Cardiacs	*Non-cardiacs*
Mean age	54.05 ± .48	49.59 ± .71
Standard deviation	7.81 ± .34	6.40 ± .50
N	126	37

The cardiacs, notwithstanding the selection, are older than the non-cardiacs. The difference in age, though statistically significant, is too small to influence to any significant extent the somatic constitution.

CLINICAL DIAGNOSIS, PHYSICAL EXAMINATION AND PAST MEDICAL HISTORY

The two groups compared are fundamentally differentiated by the fact that the individuals of one group have some form of heart disease which is absent in the other. It is of importance also to determine what other diseases or association of diseases or physiological

conditions characterize the two groups of individuals. These data are necessary to judge if the somatological characteristics may be dependent upon other than the fundamental difference between the two groups and to what extent the differential incidence of these other conditions may affect the nutritional state of the patient.

TABLE 1

Distribution of Diagnosed Pathological Conditions

	NON-CARDIACS		CARDIACS	
	Absolute number	Percent	Absolute number	Percent
Normal (no discernible pathology)	2	5.4	..	...
Heart — Hypertrophy and dilatation	..	...	57	45.2
Heart — Myocarditis	..	...	33	26.2
Heart — Endocarditis and valvular lesions	..	...	23	18.3
Heart — Aortic dilatation	..	...	8	6.3
Heart — Other lesions	..	...	22	17.5
Other circulatory diseases (arteriosclerosis, etc.)	..	...	97	77.0
Nephritis — all forms	1	2.7	11	8.7
Syphilis — all forms	12	32.4	9	7.1
Tuberculosis	..	...	1	.8
Malignant tumors — all forms	7	18.9	11	8.7
Pneumonia (all forms), bronchitis, etc.	..	...	7	5.6
Diseases of alimentary tract (other than cancer and tuberculosis)	4	10.8	..	...
Diabetes	1	2.7	12	9.5
Diseases of gall bladder and ducts	..	...	3	2.4
Arthritis	2	5.4	10	7.9
All others	12	32.4	..	...

Table 1 shows the absolute and percentage distributions of the disease conditions diagnosed in the two groups, classified into broad categories. It is to be noted that the percentage columns do not add to 100 because each patient has been entered in as many categories as the items of her diagnosis. The form of heart lesions typical of the cardiacs in this sample is delineated by the number of those (77

percent) having other circulatory diseases and of those (45.2 percent) having cardiac hypertrophy and dilatation. Nephritis and diabetes are found more frequently among the cardiacs than the non-cardiacs. On the other hand the non-cardiacs have a higher incidence of syphilis (all forms), malignancies (all forms) and diseases of the alimentary tract (other than cancer and tuberculosis).

Pearl and Ciocco's study on males reveals practically the same difference as found between non-cardiacs and cardiacs relative to the distribution of diagnosed diseases. In the males the incidence of nephritis is 2.0 percent in the non-cardiacs and 13.7 percent in the cardiacs, while in the females it is 2.7 percent and 8.7 percent respectively. Diabetes in the males is found in 2.0 percent of the non-cardiacs and 6.9 percent of the cardiacs, in the females it is found in 2.7 percent of the former group and 9.5 percent of the latter. Similarly, taking the two groups in the same order, the incidence of malignancies is in males, 34.0 percent and 22.9 percent respectively; in females, 18.9 percent and 8.7 percent; the incidence of syphilis in males, 24.0 percent and 16.0 percent; in females, 32.4 percent and 7.1 percent; and of diseases of the alimentary tract, in males, 8.0 percent and 3.4 percent; in females, 10.8 percent and 0 percent. Based on such small numbers, most of these differences between cardiacs and non-cardiacs are not in themselves significant; nevertheless the consistency of the trend in the two sexes is noteworthy. To summarize: both the males and females in this sample of hospital populations show in general the same association between certain diseases and the presence or absence of heart lesions.

It should be clearly understood that these are selected groups and that the relative incidence of the various disease categories listed cannot be regarded, for either group, as that of the general population within the same age limits. To draw any statistical conclusion on the supposition that either of these groups is a random sample of the general population would be extremely fallacious. The same admonition, *mutatis mutandis,* may be made for the following facts regarding the general health and past medical history. These, of course, are subjective statements, but there is no reason to believe that the individuals of one group are more or less truthful or have better or worse memories than the individuals of the other.

The statements of the patients in answer to the question: What has been your state of health up to the present? have been tabulated in

Table 2. Very good health was enjoyed by a higher percentage of non-cardiacs than cardiacs, and *vice versa* for the remaining categories. The differences are significant statistically, and the conclusion drawn from them is consistent with the insidious nature of the disease.

TABLE 2

State of Health Prior to Present Illness

HEALTH	CARDIACS		NON-CARDIACS	
	Absolute numbers	Percent	Absolute numbers	Percent
Very good (never ill)	45	36.0	23	62.2
Good (minor ailments only)	52	41.6	11	29.7
Fair (average amount of sickness)	16	12.8	3	8.1
Poor (frequently sick)	11	8.8	..	...
Very poor (an invalid throughout life)..	1	.8	..	...
Total	125	100.0	37	100.0

The extent to which past infections predispose to cardio-vascular diseases is not known with any degree of certainty except for syphilis and rheumatic fever. There however appears to be much evidence associating scarlet fever with the rheumatic form of heart disease (5). History of this infection has also been found with more frequency in the hypertensive individuals studied by Nuzum and Elliott (14). The investigation by Walker and O'Hare (23) does not confirm this, however. Regarding other infectious diseases, except for the immediate signs of cardiac involvement, the data are not definite. Typhoid fever is regarded as a causative factor of arteriosclerotic and hypertensive diseases from the study of Thayer (21) and more recently from those of Barach (1) and Walker and O'Hare (*loc. cit.*). Nuzum and Elliott (*loc. cit.*) do not arrive at the same conclusion. Diphtheria is believed to be a cause of heart block in later life by Butler and Levine (3) but not by Jones and White (11). Data on the late effects of pneumonia are scarce. Walker and O'Hare (*loc. cit.*) found practically the same incidence in hypertensive as in non-hypertensive individuals. Stone (20) has, however, given evidence that heart involvement is, after sepsis, the most frequent cause of death from pneumonia.

For this material, the incidence of some of the acute infectious diseases in the past history of the cardiacs and non-cardiacs is presented in Table 3 which gives the absolute and relative distributions.

TABLE 3

Past History of Acute Infectious Diseases

DISEASE	CARDIACS*		NON-CARDIACS*	
	Absolute numbers	Percent	Absolute numbers	Percent
Measles	85	68.0	29	78.4
Mumps	39	31.2	13	35.2
Scarlet Fever	21	16.8	3	8.1
Diphtheria	15	12.0	4	10.8
Rheumatic Fever	7	5.6	..	...
Typhoid Fever	26	20.8	3	8.1
Pneumonia	33	26.4	3	8.1
Influenza	43	34.4	13	35.2

* Total cardiacs = 125; total non-cardiacs = 37.

A rheumatic fever history is not given by any of the non-cardiacs. The greatest differences between the two groups are found for scarlet-fever, typhoid fever and pneumonia. Of these, only with regard to the last named disease is the difference statistically significant. The small number of cases involved renders any interpretation except the mere enumeration impossible, especially when one keeps in mind the contradictory findings cited above.

A fact of interest in the constitutional study of women is the age of menarche. It is dependent upon the anatomical development and physiological state of the individual, influenced by the state of health and probably also by the environmental conditions, race and social status. For the women in this study the constants are as follows:

	Cardiacs	*Non-cardiacs*
Mean age at menarche	14.32 ± .10	14.56 ± .21
Standard deviation	1.62 ± .07	1.84 ± .15
N	119	36

The difference between the means is too small to be of statistical significance. This may be taken as an indication that up to that age the cardiacs and non-cardiacs were on the average equal with respect to those factors directly correlated with the onset of menstruation.

TABLE 4

Blood Pressure in Cardiacs and Non-cardiacs

	N	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Systolic								
Cardiacs	126	173.50 ± 2.09	175.33 ± 2.61	34.82 ± 1.48	20.07 ± .89	90	270	180
Non-cardiacs ..	37	127.16 ± 1.65	127.86 ± 2.07	14.90 ± 1.17	11.72 ± .93	90	150	60
Diastolic								
Cardiacs	126	96.27 ± 1.30	95.77 ± 1.63	21.68 ± .92	22.52 ± 1.00	45	150	105
Non-cardiacs ..	37	76.89 ± 1.06	76.76 ± 1.33	9.54 ± .75	12.41 ± .99	56	90	34
Pulse pressure								
Cardiacs	126	78.73 ± 1.53	77.30 ± 1.92	25.48 ± 1.08	32.36 ± 1.51	20	150	130
Non-cardiacs ..	37	53.38 ± 1.49	51.25 ± 1.87	13.45 ± 1.05	25.20 ± 2.10	30	73	43

From the medical examination a few items directly related to this study have been statistically analyzed and comparisons made between cardiacs and non-cardiacs. The biometric constants for systolic and diastolic blood pressure and pulse pressure are given in Table 4. The influence of the high incidence of hypertension among the cardiacs in this sample is clearly seen when one compares the means of the two groups for each variable. The magnitude of the difference for the arithmetic means as well as for the absolute and relative measures of variability is in agreement with the nature of the material.

The potential energy of the arterial system as measured by the diastolic pressure is 25.2 percent higher in the cardiacs than in the non-cardiacs, while the pulse pressure which is regarded as a measure of the kinetic energy of the ventricular output at each systole is 47.5 percent greater in the cardiacs. The systolic pressure is 36 percent higher in this group. These differences are better appreciated when the pressures of the two groups are compared with those of "normal" individuals of the same average age. Data on the natural history of blood pressure relative to increasing age are scarce. The consensus of clinical opinion is that the limits of normality for systolic pressure are between 110 and 140 or 150 mm. A finding above or below these limits is regarded as pathologic. Consequently only the changes with age within these limits have been published, as for example, in the reports of life insurance companies.

Of greater biological interest because the data have not been so selected are the reports of Stocks (19) on the age variation of blood pressure in children and young adults, and of Saller (18) who has analyzed the same factor in a series of hospital patients free from clinical evidence of circulatory (aside from blood pressure) and kidney diseases, anemias, diabetes, and other glandular disorders. From his data which include individuals from 3 to 89 years of age the expected mean pressure for the cardiac and non-cardiac women in relation to their respective age distributions have been calculated. The results are as follows:

	Mean calculated "normal" pressure in mm.		
	Systolic	*Diastolic*	*Pulse*
Cardiacs	145.67	84.19	61.70
Non-cardiacs	139.37	81.68	58.05

Comparing with the constants given in Table 4 we find that the non-cardiacs in this material have a mean systolic pressure 8.8 percent lower than the expected on the basis of Saller's data, a diastolic

TABLE 5

Heart Measurements in Cardiacs and Non-cardiacs

	N	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Cardiac dullness to left of M. S. L. (cm.)								
Cardiacs	112	11.48 ± .12	11.23 ± .16	2.00 ± .09	17.42 ± .81	6.0	16.0	10.0
Non-cardiacs	33	8.99 ± .18	9.13 ± .23	1.52 ± .13	16.91 ± 1.44	6.0	12.0	6.0
Cardiac dullness to right of M. S. L. (cm.)								
Cardiacs	108	3.12 ± .04	3.10 ± .05	.68 ± .03	21.80 ± 1.05	2.0	5.0	3.0
Non-cardiacs	31	2.62 ± .09	2.95 ± .11	.77 ± .07	29.38 ± 2.73	1.0	4.0	3.0
Distance of P. M. I. from suprasternal notch (cm.)								
Cardiacs	113	17.32 ± .09	17.36 ± .11	1.50 ± .08	8.66 ± .39	12.0	20.0	8.0
Non-cardiacs	26	17.19 ± .27	17.29 ± .34	2.07 ± .19	12.04 ± 1.14	13.0	21.0	8.0
Distance of P. M. I. from midline (cm.)								
Cardiacs	115	10.47 ± .12	10.45 ± .15	1.93 ± .09	18.43 ± .85	6.0	15.3	9.3
Non-cardiacs	27	8.43 ± .20	8.54 ± .25	1.56 ± .14	18.51 ± 1.76	6.0	11.5	5.5

pressure 5.9 percent lower and a pulse pressure 8.0 percent less than the expected. These differences are relatively small and show that the blood pressure of these women as a group falls well within the limit of "normal". The cardiacs instead have an actual systolic pressure 19.1 percent greater than expected for their age, a diastolic pressure 14.3 percent higher and a pulse pressure 27.6 percent greater than the calculated. These differences well indicate the greater effort of the heart that is necessary in these cardiacs to overcome the deficiency of the circulatory system and satisfy the requirements of the organism.

Another sign of the degree of mechanical effort made by the heart muscle is its size, especially that of its ventricles. It is well known that, excepting mitral stenosis, all the more common forms of cardiac diseases cause hypertrophy of the ventricles. In this material the heart measurements were obtained by the usual methods of palpation and auscultation and the calculated constants are presented in Table 5.

From this table the following points are noted.

1. On the average, the hearts of the cardiacs are more enlarged transversally than those of the non-cardiacs.

2. The point of maximum impulse (P. M. I.) is at an equal average distance from the suprasternal notch for both the cardiacs and non-cardiacs.

3. The absolute dispersion measured by the standard deviation is significantly greater in the cardiacs for the measure of cardiac dullness to the left of midline. The non-cardiacs show a higher absolute variability which is very probably significant for the distance between P. M. I. and suprasternal notch.

4. The coefficient of variation is very probably significantly different for only two dimensions: dullness to right of M. S. L. and the distance between the P. M. I. and suprasternal notch. The non-cardiacs show superiority for both.

These findings correspond to expectation. From the fact that the distance of the P. M. I. from the midline is greater in the cardiacs than in the non-cardiacs while the distance of this point from the suprasternal notch is equal in both groups it may be inferred, by analogy to geometric figures, that another difference between these two groups is the position of the heart in the chest. An indication of the relative

position of the heart, horizontal or vertical, may be obtained from the following ratio:

$$\frac{\text{Distance P. M. I. from midline}}{\text{Distance P. M. I. from suprasternal notch}} \quad 100$$

This cardiac index[1] calculated for each individual has the following mean values:

	Cardiacs	*Non-cardiacs*
Mean cardiac index	59.95 ± .80	49.00 ± 1.43
Standard deviation	12.50 ± .57	10.60 ± 1.01
N	111	25

The significantly different arithmetic means bear out the inference that the cardiacs have a more horizontal heart than the non-cardiacs. A tentative conclusion of another order may be reached also. It is known that in individuals with wide short chests the heart is more horizontally placed than in those with a long narrow thorax; therefore it may be assumed that the cardiacs in this material have a relatively shorter wider chest than the non-cardiacs. This will actually be confirmed in the pages that follow.

From the above analysis the most striking divergences observed between cardiacs and non-cardiacs, as groups, may be summarized as follows. The cardiacs are characterized by 100 per cent incidence of heart disease accompanied by a high percentage of other circulatory diseases, preponderance of nephritis and diabetes, less frequent incidence of syphilis, malignancies and diseases of the gastro-intestinal tract, somewhat inferior general health and a greater frequency of scarlet fever, typhoid fever and pneumonia in the past, markedly higher systolic and diastolic blood pressure, the heart enlarged transversally and apparently more horizontal in position.

[1] Its meaning is evident. The angle formed at the apex of the heart by a straight line following the left border and another from the apex to the sternum will be more acute the more the heart is horizontally placed. This same property is true but to a diminished degree for the angle formed by the lines: suprasternal notch to P. M. I. and P. M. I. to midline. These three points are the apices of a right triangle. The ratio here used is equivalent to: side of the triangle/hypotenuse = cosine of contained angle. Therefore the higher the value of this ratio the more acute will be the angle.

DIRECT ANTHROPOMETRIC MEASUREMENTS

Table 6 presents the arithmetic mean, median, standard deviation, coefficient of variation, minimum and maximum observations for each of the 22 somatic variables directly measured upon the living subject. For each variable the unit of measurement and the number of individuals measured are indicated.

From Table 6 the following points are to be noted:

1. In stature, auditory canal height, suprasternal notch height and trunk length the non-cardiacs are slightly superior to the cardiacs by amounts statistically insignificant. The measures of the lower costal margin height and sitting height have greater mean values for the cardiacs but again this difference is of no statistical significance.

2. The cardiacs are heavier than the non-cardiacs, on the average, by 11.89 ± 1.63 kgs. This difference is 7.3 times its probable error and it amounts to a relative superiority of 20.8 percent.

3. The span is found to be on the average equal in both groups.

4. Each horizontal diameter (biacromial, biiliac and greatest hip breadth) and chest depth is larger in the cardiacs than in the non-cardiacs by an amount statistically significant.

5. The cardiacs also have marked and significantly greater mean values for neck girth, chest girth (expiration), chest girth (rest), chest girth (inspiration) and umbilicus girth.

6. For head length and breadth the differences between cardiacs and non-cardiacs are statistically significant. The cardiacs are superior in both measurements, as also for the head girth. For this latter measurement however, the difference may be regarded as within the limits of sampling variation. The explanation of this apparent inconsistency will appear when the cephalic index is discussed.

7. The length and breadth of the ear show significantly higher mean values in the cardiacs.

8. The absolute variability, measured by the standard deviation, is significantly greater in the cardiacs for body weight and neck girth.

9. The measure of relative variability, coefficient of variation, is significantly different between the two groups for only one variable: neck girth. For this the cardiacs are more variable.

TABLE 6

Biometric Constants of Direct Somatic Measurements
(Females 40-69 years of age)

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Body weight (kg.)								
Cardiacs	114	68.95 ± .98	67.06 ± 1.22	15.48 ± .69	22.45 ± 1.05	35.0	116.0	81.0
Non-cardiacs	34	57.06 ± 1.30	55.33 ± 1.63	11.21 ± .92	19.65 ± 1.67	37.3	84.6	47.3
Stature (cm.)								
Cardiacs	126	156.51 ± .41	157.30 ± .51	6.87 ± .29	4.39 ± .19	126.0	169.5	43.5
Non-cardiacs	37	156.56 ± .83	156.59 ± 1.04	7.47 ± .59	4.77 ± .37	127.6	170.0	42.4
Height at ext. auditory meatus (cm.)								
Cardiacs	126	143.02 ± .39	143.79 ± .49	6.54 ± .28	4.57 ± .19	113.8	155.6	41.8
Non-cardiacs	37	143.45 ± .83	144.32 ± 1.04	7.47 ± .59	5.21 ± .41	114.4	156.1	41.7
Height at suprasternal notch (cm.)								
Cardiacs	126	127.98 ± .36	128.68 ± .45	5.99 ± .25	4.68 ± .20	102.7	144.4	41.7
Non-cardiacs	37	128.72 ± .72	129.11 ± .90	6.46 ± .51	5.02 ± .39	104.1	141.2	37.1
Height at lower costal margin (cm.)								
Cardiacs	123	102.42 ± .33	102.63 ± .41	5.37 ± .23	5.24 ± .23	80.2	113.2	33.0
Non-cardiacs	37	101.15 ± .56	101.62 ± .70	5.08 ± .40	5.02 ± .39	80.1	110.3	30.2

TABLE 6—*Continued*

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Height: sitting (cm.)								
Cardiacs	126	82.72 ± .23	83.15 ± .29	3.76 ± .16	4.55 ± .19	69.8	90.8	21.0
Non-cardiacs	37	83.62 ± .42	83.98 ± .53	3.79 ± .30	4.53 ± .36	71.0	89.0	18.0
Trunk length (cm.)								
Cardiacs	124	53.87 ± .18	54.06 ± .23	2.99 ± .13	5.55 ± .24	43.1	59.4	16.3
Non-cardiacs	37	54.56 ± .35	54.89 ± .44	3.16 ± .25	5.79 ± .46	46.1	58.5	12.4
Span (cm.)								
Cardiacs	124	158.75 ± .44	160.00 ± .55	7.28 ± .31	4.59 ± .20	134.9	172.5	37.6
Non-cardiacs	36	158.20 ± .84	158.18 ± 1.05	7.47 ± .59	4.72 ± .38	136.8	176.1	39.3
Head length (cm.)								
Cardiacs	125	18.36 ± .04	18.39 ± .05	0.71 ± .03	3.87 ± .17	16.4	19.7	3.3
Non-cardiacs	37	17.99 ± .09	18.08 ± .11	0.79 ± .06	4.39 ± .34	16.0	19.6	3.6
Head breadth (cm.)								
Cardiacs	125	14.88 ± .04	14.86 ± .05	0.65 ± .03	4.37 ± .19	12.2	17.0	4.8
Non-cardiacs	37	14.28 ± .08	14.31 ± .10	0.74 ± .06	5.19 ± .41	12.7	15.4	2.7
Breadth—biacromial (cm.)								
Cardiacs	125	34.84 ± .12	34.78 ± .15	1.96 ± .08	5.63 ± .24	29.2	38.6	9.4
Non-cardiacs	37	33.86 ± .22	34.18 ± .28	1.97 ± .15	5.82 ± .46	29.3	38.0	8.7

TABLE 6—*Continued*

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Breadth—biiliac (cm.)								
Cardiacs	123	29.44 ± .14	29.35 ± .18	2.22 ± .10	7.54 ± .33	21.2	35.5	14.3
Non-cardiacs	37	28.03 ± .25	28.21 ± .31	2.28 ± .18	8.13 ± .64	23.5	35.8	12.3
Breadth—greatest hip (cm.)								
Cardiacs	124	35.35 ± .21	35.10 ± .26	3.42 ± .15	9.68 ± .42	26.5	50.0	23.5
Non-cardiacs	36	33.78 ± .46	34.17 ± .58	4.10 ± .33	12.14 ± .98	26.2	40.9	14.7
Chest depth (cm.)								
Cardiacs	125	21.03 ± .14	20.92 ± .18	2.29 ± .10	10.89 ± .47	16.0	26.1	10.1
Non-cardiacs	37	18.73 ± .28	18.14 ± .35	2.53 ± .20	13.51 ± 1.08	13.0	22.9	9.9
Girth—head (cm.)								
Cardiacs	123	54.84 ± .09	54.79 ± .11	1.52 ± .07	2.77 ± .12	51.5	58.0	6.5
Non-cardiacs	37	54.58 ± .19	54.49 ± .24	1.75 ± .14	3.21 ± .25	51.2	58.7	7.5
Girth—neck (cm.)								
Cardiacs	126	34.45 ± .18	34.15 ± .23	2.95 ± .13	8.56 ± .37	27.5	46.5	19.0
Non-cardiacs	37	32.33 ± .23	32.04 ± .29	2.10 ± .16	6.50 ± .51	26.6	37.0	10.4
Girth—chest: expiration (cm.)								
Cardiacs	125	89.42 ± .58	88.95 ± .73	9.65 ± .41	10.79 ± .47	60.5	121.8	61.3
Non-cardiacs	36	83.34 ± .90	81.50 ± 1.13	8.00 ± .64	9.60 ± .77	67.0	97.0	30.0

TABLE 6—*Continued*

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Girth—chest: rest (cm.)								
Cardiacs	125	90.90 ± .58	90.27 ± .73	9.67 ± .41	10.64 ± .46	61.5	122.0	60.5
Non-cardiacs	36	85.28 ± .89	85.00 ± 1.12	7.95 ± .63	9.32 ± .75	67.9	98.0	30.1
Girth—chest: inspiration (cm.)								
Cardiacs	125	92.86 ± .59	92.58 ± .74	9.86 ± .42	10.62 ± .46	63.5	122.5	59.0
Non-cardiacs	36	87.09 ± .89	85.63 ± 1.12	7.95 ± .63	9.13 ± .73	69.3	100.0	30.7
Girth at umbilicus (cm.)								
Cardiacs	125	105.60 ± 1.02	100.13 ± 1.28	16.89 ± .72	15.99 ± .70	64.0	175.0	111.0
Non-cardiacs	36	85.83 ± 1.59	84.29 ± 1.99	14.14 ±1.12	16.47 ± 1.34	62.0	119.5	57.5
Ear length (cm.)								
Cardiacs	123	6.41 ± .03	6.36 ± .04	0.46 ± .02	7.18 ± .31	5.4	7.5	2.1
Non-cardiacs	37	6.22 ± .05	6.23 ± .06	0.44 ± .03	7.07 ± .56	5.1	7.5	2.4
Ear breadth (cm.)								
Cardiacs	123	3.43 ± .02	3.42 ± .03	0.37 ± .02	10.79 ± .47	2.1	4.2	2.1
Non-cardiacs	37	3.22 ± .05	3.01 ± .06	0.43 ± .03	13.35 ± 1.07	2.0	4.1	2.1

10. For both cardiacs and non-cardiacs body weight is the most variable character; head girth, the least. This, of course, is to be expected.

11. The arithmetic mean and the median for each character practically coincide except for the umbilicus girth in the cardiacs. Therefore the distributions for each dimension may be regarded as symmetrical with the exception of that of the umbilicus girth which in the cardiacs shows some positive skewness.

The results obtained by comparison of the direct anthropometric measurements may be summarized as follows: In this sample, the cardiacs as a group have approximately the same stature and correlated vertical dimensions as the non-cardiacs, but are substantially and significantly heavier. This greater weight is associated with larger girths generally, and particularly with a larger umbilicus girth.

These dimensions are those most directly affected by the dietary regimen and metabolic activity of the individual. With this fact established two possibilities will be investigated as this study proceeds. Either for each group there is a different distribution of somatological types or there is a tendency for individuals with the same somatic habitus to be heavier among the cardiacs.

For a better visualization of the difference between cardiacs and non-cardiacs, Table 7 and Plates I, II and III are presented. These concern two patients: a cardiac, B 89, and a non-cardiac, D 34. Their measurements are sufficiently close to those of their respective groups so that they may be regarded respectively as an "average" cardiac and an "average" non-cardiac. They possess the same bodily habitus, both having been classed as intermediates. While it is evident that the measurements of these two women do not show for every single character the same relationship as the means of Table 6, they do on the whole give a picture of the divergences between the two groups. The cardiac is heavier and bigger all around, especially at the umbilicus.

The findings of Pearl and Ciocco on males are fundamentally identical to these on females. We also found no significant difference between cardiacs and non-cardiacs for height measurements. The male cardiacs were superior in weight by 9.8 percent when compared to the non-cardiacs; in the females the cardiacs have 20.8 percent greater weight than the non-cardiacs. The significant superiority of the female cardiacs in the horizontal diameters and girths was also observed in the male cardiacs but to a lesser degree. Head length and breadth,

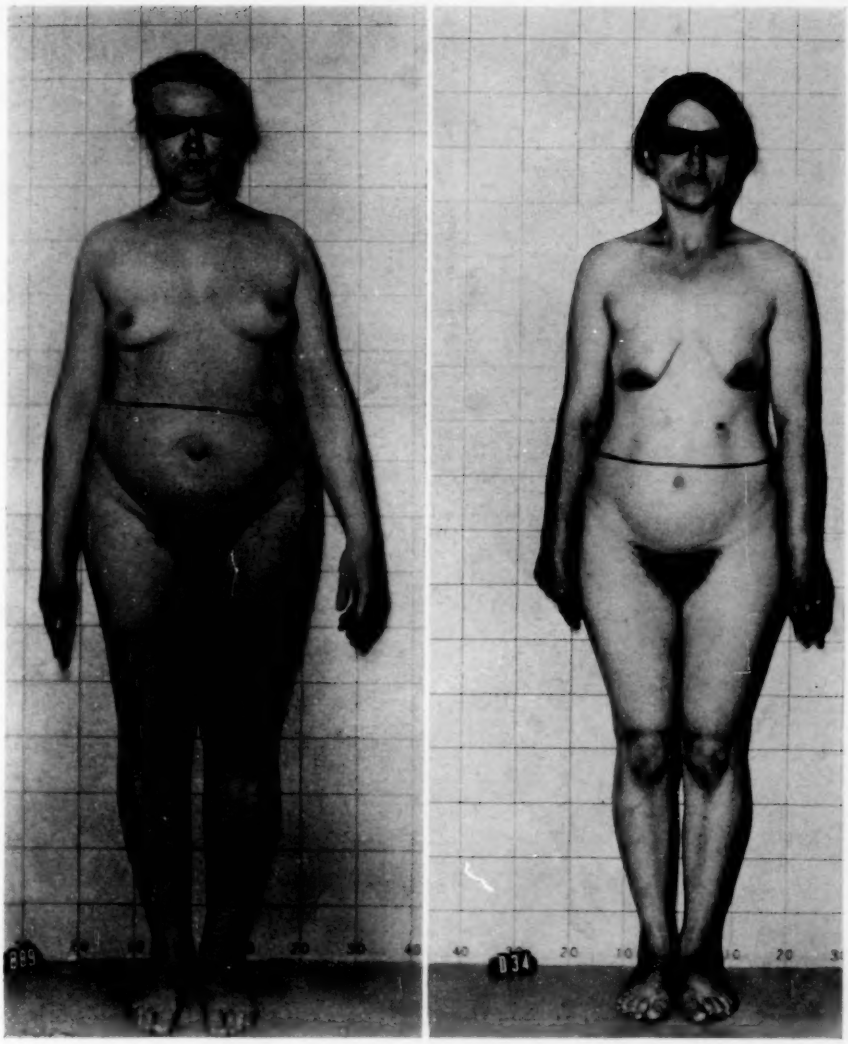

PLATE I. FRONTAL ASPECT OF "AVERAGE" CARDIAC (B 89) AND NON-CARDIAC (D 34) INDIVIDUAL

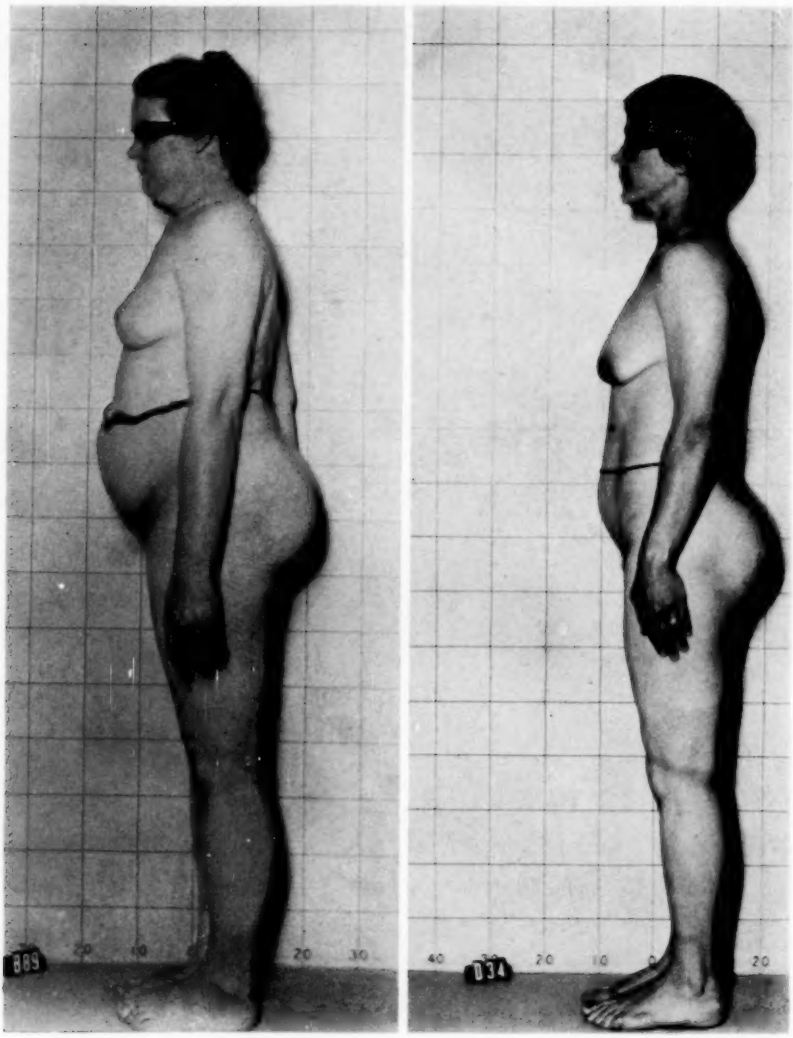

PLATE II. LATERAL ASPECT OF "AVERAGE" CARDIAC (B 89) AND NON-CARDIAC (D 34) INDIVIDUAL

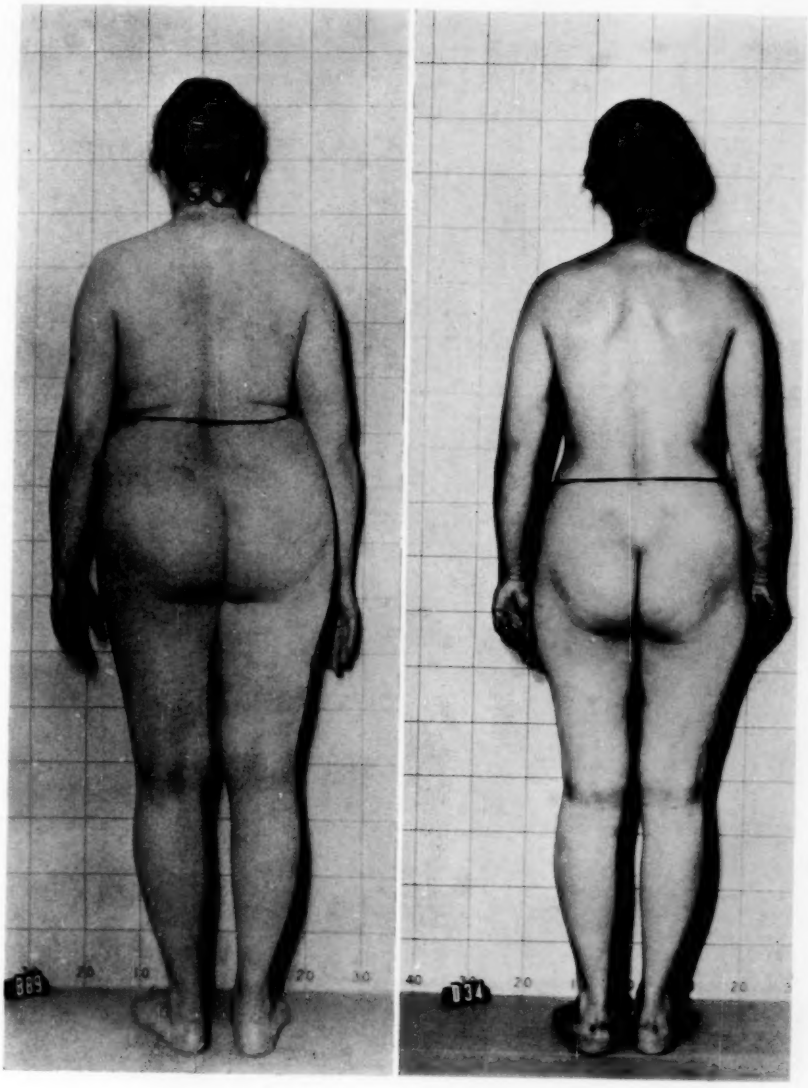

PLATE III. POSTERIOR ASPECT OF "AVERAGE" CARDIAC (B 89) AND NON-CARDIAC (D 34) INDIVIDUAL

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TABLE 7

Comparison of "Average" Cardiac (B 89) and "Average" Non-cardiac (D 34)

CHARACTER	CARDIAC (B 89)	NON-CARDIAC (D 34)
Age (years)	44	41
Body weight (kg.)	72.3	59.8
Stature (cm.)	158.1	159.7
Height at ext. auditory meatus (cm.)	145.0	145.9
Height at suprasternal notch (cm.)	131.1	131.0
Height at lower costal margin (cm.)	104.0	100.2
Height—sitting (cm.)	82.2	87.9
Trunk length (cm.)	54.4	58.3
Span (cm.)	164.7	160.4
Head length (cm.)	18.8	19.1
Head breadth (cm.)	14.7	15.1
Breadth biacromial (cm.)	36.1	32.4
Breadth biiliac (cm.)	29.3	29.0
Breadth—greatest hip (cm.)	37.0	35.6
Chest depth (cm.)	19.2	18.4
Girth—head (cm.)	56.0	55.0
Girth—neck (cm.)	34.0	33.5
Girth—chest: expiration (cm.)	86.8	84.0
Girth—chest: rest. (cm.)	88.8	86.0
Girth—chest: inspiration (cm.)	91.4	87.2
Girth at umbilicus (cm.)	109.6	83.0
Ear length (cm.)	6.1	5.8
Ear breadth (cm.)	3.3	3.5

ear length and breadth, significantly higher in cardiac than in non-cardiac females are found to be practically equal in cardiac and non-cardiac males. The divergences in variability, both absolute and relative, between cardiacs and non-cardiacs which were found for a number of characters in the study on males, do not appear in these females except for body weight and neck girth for which, as in males, the cardiacs are more variable.

It can be then concluded that the basic differences between male cardiacs and non-cardiacs are even more accentuated in the females and particularly in regard to those physical characters especially affected by nutrition. On the basis of these and other observations which will be discussed later, Pearl and Ciocco enunciated the hypothesis that the greater weight and correlated dimensions of the cardiacs in their sample were a consequence of relative overeating and lack of physical exercise. Therefore, in this study, the author has attempted to add as much information on this point as the material permitted by tabulating the responses obtained to the questions regarding the patient's degree of appetite and regularity of bowel movement.

TABLE 8

Degree of Appetite and Regularity of Bowel Movements

	CAPDIACS		NON-CARDIACS	
	Absolute number	Percent	Absolute number	Percent
Appetite				
Eat heartily	51	40.8	15	42.9
Eat average	47	37.6	11	31.4
Eat sparingly	27	21.6	9	25.7
Total	125	100.0	35	100.0
Bowel movements				
Regular 1-2 times daily	71	56.7	25	69.4
Chronic constipation or irregularity	54	43.3	11	30.6
Total	125	100.0	36	100.0

Table 8 shows that the majority of patients among both the cardiacs and non-cardiacs admit being hearty eaters. The percentages in the remaining two categories are practically equal for the two groups. This item besides being a rough index of the quantity of food ingested serves

also to check whether anorexia may not be regarded as one factor in the relative thinness of the non-cardiacs. It is evident that it is not so. From the table it is seen that a higher percentage of cardiacs, in this material, complain of irregular bowel movements or chronic constipation. While the differences between the two groups may be attributed to sampling error they are highly interesting. It is generally recognized (13) that predisposing causes to constipation are the quality and quantity of food eaten and the lack of physical exercise. Therefore, the fact that constipation is more prevalent among cardiacs while they are at least as hearty eaters as the non-cardiacs strengthens the hypothesis that the accumulation of fat in the cardiacs may be in part the effect of dietary habits not in keeping with their physical activity.

HEART AND SOMATIC MEASUREMENTS

The measurements of the heart show that on the average the cardiacs have a greater transverse diameter than the non-cardiacs. There exist, also, marked physical differences between cardiacs and non-cardiacs, the former being superior in weight and body girths. While there is thus an obvious *group* association between heart size and body size, are there corresponding correlations within each group, cardiac and non-cardiac? To answer this question it is necessary to determine what is the degree of correlation between heart measurements and external physical dimensions in both groups. Accurate investigations by Bardeen (2), Eyster (7), Treadgold (22), and others who have employed roentgenograms (orthodiagrams) show that in the "normal" the transverse diameter of the heart is directly proportionate to the weight and chest girth and inversely proportionate to the stature, other factors being constant. The data at hand obtained by the cruder method of palpation and auscultation do not permit use of their results for purposes of comparison.

Using the measurement of the distance of the point of maximum impulse (P. M. I.) from midline as a rough index of the transverse diameter of the heart and calculating its correlation with stature, weight, chest girth (rest) and the chest girth (rest)/stature index, the values of r shown in Table 9 are obtained.

In the cardiacs the coefficients do not differ significantly from zero except for the correlation with body weight. The reverse condition is apparent in the non-cardiacs. For this group, however, the number of cases is too small to warrant entire confidence in the figures, even

TABLE 9

Correlations Between Bodily Dimensions and Distance of P. M. I. from Mid-line

CHARACTER	CARDIACS		NON-CARDIACS	
	N	*r*	*N*	*r*
Stature	114	+.16 ± .06	27	−.41 ± .11
Weight	103	+.26 ± .06	26	+.21 ± .13
Chest girth (rest.)	113	+.18 ± .06	26	+.46 ± .11
Umbilicus girth	113	+.12 ± .06	26	+.54 ± .09
Chest girth/stature	113	+.11 ± .06	26	+.41 ± .11

though all the coefficients but one are more than three times their respective probable errors, and though the negative value for stature, and the positive value for chest girth are in agreement with the observations of the above mentioned authors. In terms of the probable error of differences the correlation coefficients between the P. M. I. from midline and stature and the umbilicus girth are significantly different in cardiacs and non-cardiacs, but are only probably significant in regard to chest girth (rest) and chest girth (rest)/stature.

In a tentative fashion, because of the small number of cases, one can assume that another characteristic difference between the two groups is that in the non-cardiacs there is covariation between somatic growth and heart width which is not present in the cardiacs. This can be shown more clearly in another way. From the values of *r* found for the *non-cardiacs* the regression lines can be calculated which, with due precautions, will indicate the "normal" linear relation between somatic growth and heart width. The resulting equations are:

P. M. I. from midline in cm. = 20.36 − .08 (stature in cm.)
P. M. I. from midline in cm. = .23 + .10 (chest girth in cm.)
P. M. I. from midline in cm. = 3.05 + .06 (umbilicus girth in cm.)
P. M. I. from midline in cm. = 2.95 + .10 (chest girth/stature in percent).

The oscillations of the observed heart dimensions around the interpolated curve can be measured by the *standard deviation* (square root of the mean of the squared differences between actual and theoretical values). For each curve, comparison of the standard deviation of the

cardiacs with that of the non-cardiacs will indicate the degree of dispersion of the actual measurements with respect to the calculated "normal". For the cardiacs and for the non-cardiacs the standard deviations are as follows.

	Standard deviation from theoretical values	
	Non-cardiacs	*Cardiacs*
P. M. I. from midline and stature	1.48 ± .14	2.87 ± .13
P. M. I. from midline and chest girth (rest)	1.43 ± .13	2.47 ± .11
P. M. I. from midline and umbilicus girth	1.42 ± .13	2.44 ± .11
P. M. I. from midline and chest girth (rest)/ stature	1.47 ± .14	2.55 ± .11

For each curve the deviation of the cardiacs is not only significantly larger than that of the non-cardiacs but also practically double in size. This comparison gives a more exact meaning to the results obtained by the use of the correlation coefficient. It is also in line with the clinical observations made by the above mentioned authors. For example, Eyster (*loc. cit.*) by a similar procedure found that 86 percent of healthy hearts fell within ± 10 percent of the calculated normal size while only 24 percent of diseased hearts fell within this same range. The importance of these observations for the study of somatological constitution cannot be over-emphasized: they indicate the association between disease and disequilibrium in organic growth. In this particular case, the disproportion between somatic growth and heart width may be regarded as an expression of the anatomical foundation for the somatological differences found between cardiacs and non-cardiacs.

COMPARATIVE DATA

In the study of constitutional somatology as well as physical anthropology, intergroup comparisons are necessary in order to derive the limits within which any conclusion should be maintained. Otherwise, the lack of "control" data, the influence of the various factors affecting the particular material, may lead to undue enthusiasm or universal assertions not warranted by the facts. In the interest of this study and of others which may be undertaken, the data on American females whose ages and conditions are more or less comparable to those of this material are given in the following tables. These data are taken from Hrdlička's (10) *Old Americans* (body weight and stature only),

Draper's (6) *Human Constitution* and the recent paper of Feigenbaum and Howat[2] (8). Each table is arranged in descending order of the arithmetic means.

BODY WEIGHT, STATURE AND CHEST GIRTH

These measurements presented in Tables 10, 11, and 13 will be discussed together with derivative measures of Tables 12 and 14. Table 12 gives the body weight ratio (kilograms per 10 cm. of stature), the values of which are calculated directly from the means of Tables 10 and 11, according to the following formula:

$$\frac{10 \times \text{mean body weight in kg.}}{\text{Mean stature in cm.}}$$

Table 14 gives the mean computed cylindrical body volume, an anthropometric index first adopted by Pearl and Ciocco and by them discussed (48). It is computed from the following formula: Mean computed cylindrical body volume $= .079577$ (chest girth in cm.)$^2 \times$ Stature in cm.

The 14 series in weight measurements may be divided into three sections. The first includes only the markedly overweight group of gall-bladder disease, the second is headed by the cardiacs and includes the three groups of Old Americans, Draper's nephritis and hypertension, and asthma groups, and the cholecystitis and diabetes groups of Feigenbaum and Howat. The third section contains the non-cardiacs followed by the remaining groups. In this form, the relative overweight of the cardiacs as seen above, in broad general terms, may be regarded as confirmed by the comparative data. Between the heaviest and the lightest group the difference is 32.5 percent of the mean of the latter.

In Stature instead the tallest group is superior by 7.9 percent of the mean height of the shortest. This difference, as is evident in Table 11, is due to the influence of Hrdlička's Old Americans who are racially more homogeneous and therefore different from the hospital population which forms the material of the remaining data.

The different relations between Height and Weight for the various groups are clearly brought forth by Table 12, which gives the mean Body Weight Ratio. It is of interest, though not unexpected, to observe that for this index the order of the several groups is very similar to that of the body weight. Per 10 cm. of stature the gall-bladder group weighs 4.66 kgs. followed closely by the cardiacs. The relatively lightest group is the pernicious anemia.

The same four groups which have the highest mean Body Weight (not including Old Americans and the data of Feigenbaum and Howat) have also the greatest Chest Circumferences. These are the cardiacs, the gall bladder

[2] From this report the following measurements have been taken: stature, weight, biacromial diameter, head breadth, head length, and ear length. Due to a difference in anthropometric technique the data on chest girth, chest depth, biiliac diameter and ear breadth have not been extracted.

TABLE 10

Mean Body Weight (in Kilograms) of Females with Various Diseases

ORDER	GROUP	MEAN AGE OR AGE LIMITS (*yrs.*)	MEAN BODY WEIGHT (*Kg.*)	*N*	AUTHORITY
1	Gall bladder disease	43.57	72.5	26	Draper (6) p. 334
2	*Cardiacs*	*54.05± .48*	*68.95± .98*	*114*	*This paper*
3	Old Americans. Lab. Series. No data as to disease	40-49	65.27	34	Hrdlička (10) p. 102
4	Old Americans. Lab. Series. No data as to disease	Above 59	64.50	3	Hrdlička (10) p. 102
5	Cholecystitis	40.8	62.87	37	Feigenbaum and Howat (8) p. 132
6	Old Americans. Lab. Series. No data as to disease	50-59	62.64	26	Hrdlička (10) p. 102
7	Diabetes	52.3	62.10	52	Feigenbaum and Howat (8) p. 132
8	Nephritis and hypertension	33.50	60.9	20	Draper (6) p. 334
9	Asthma	37.72	60.4	11	Draper (6) p. 334
10	*Non-Cardiacs*	*49.59± .71*	*57.06±1.30*	*34*	*This paper*
11	Peptic ulcers	44.1	56.97	12	Feigenbaum and Howat (8) p. 132
12	Tuberculosis	54.62	56.6	28	Draper (6) p. 334
13	Gastric and duodenal ulcer	39.17	55.2	9	Draper (6) p. 334
14	Pernicious anemia	52.39	54.8	20	Draper (6) p. 334

TABLE 11

Mean Stature (in Centimeters) of Females with Various Diseases

ORDER	GROUP	MEAN AGE OR AGE LIMITS (*yrs.*)	MEAN STATURE (*cm.*)	*N*	AUTHORITY
1	Old Americans. Lab. Series. No data as to disease	Above 59	166.07	3	Hrdlička (10) p. 80
2	Old Americans. Lab. Series. No data as to disease	40-49	162.42	36	Hrdlička (10) p. 80
3	Nephritis and hypertension	33.50	161.16	20	Draper (6) p. 334
4	Old Americans. Lab. Series	50-59	159.18	27	Hrdlička (10) p. 80
5	Tuberculosis	54.62	159.10	28	Draper (6) p. 334
6	Asthma	37.72	159.04	11	Draper (6) p. 334
7	Pernicious Anemia	52.39	158.78	20	Draper (6) p. 334
8	*Non-cardiacs*	*49.59± .71*	*156.56± .83*	*37*	*This paper*
9	*Cardiacs*	*54.05± .48*	*156.51± .41*	*126*	*This paper*
10	Peptic ulcers	44.1	156.21	12	Feigenbaum and Howat (8) p. 132
11	Gastric and duodenal ulcers	39.17	156.00	11	Draper (6) p. 334
12	Gall bladder disease	43.57	155.62	32	Draper (6) p. 334
13	Diabetes	52.3	154.69	52	Feigenbaum and Howat (8) p. 132
14	Cholecystitis	40.8	153.92	37	Feigenbaum and Howat (8) p. 132

disease, the asthma and the nephritis and hypertension groups. The difference between the first and last group of the whole series is only 11.5 percent of the mean chest girth of the latter. This is really small for a measurement so affected by nutrition, different anthropometric technique, etc.

The values of the cylindrical body volume are given in Table 14. The same four groups mentioned above occupy the first half of the series. The cardiacs have definitely the largest body volume and the tuberculosis group the least, the difference with respect to the latter equalling 22.3 percent.

TABLE 12

Mean Body Weight Ratio (Kilograms per 10 cm. of Stature) of Females with Various Diseases

(Computed from the means of Tables 10 and 11)

ORDER	GROUP	MEAN AGE OR AGE LIMITS (*yrs.*)	MEAN NUMBER OF KILOGRAMS PER 10 CM. OF STATURE
1	Gall bladder disease	43.57	4.66
2	*Cardiacs*	*54.05± .48*	*4.41*
3	Cholecystitis	40.8	4.08
4	Old Americans. Lab. Series. No data as to disease	40-49	4.02
5	Diabetes	52.3	4.01
6	Old Americans. Lab. Series. No data as to disease	50-59	3.94
7	Old Americans. Lab. Series. No data as to disease	Above 59	3.88
8	Asthma	37.72	3.80
9	Nephritis and hypertension	33.50	3.79
10	Peptic ulcers	44.1	3.65
11	*Non-cardiacs*	*49.59± .71*	*3.64*
12	Tuberculosis	54.62	3.56
13	Gastric and duodenal ulcers	39.17	3.54
14	Pernicious anemia	52.39	3.30

TABLE 13

Mean Chest Circumference at Expiration (in Centimeters) of Females With Various Diseases

(Age data given in Table 10)

ORDER	GROUP	MEAN CHEST CIRCUMFERENCE AT EXPIRATION* (*cm.*)	*N*	AUTHORITY
1	*Cardiacs*	*89.42± .58*	*125*	*This paper*
2	Gall bladder disease	88.38	31	Draper (6) p. 335
3	Asthma	84.21	10	Draper (6) p. 335
4	Nephritis and hypertension	83.89	20	Draper (6) p. 335
5	Pernicious Anemia	83.79	15	Draper (6) p. 335
6	*Non-cardiacs*	*83.34± .90*	*36*	*This paper*
7	Gastric and duodenal ulcers	82.55	11	Draper (6) p. 335
8	Tuberculosis	80.21	28	Draper (6) p. 335

* Mean circumference in the case of the Draper data.

TABLE 14

Computed Cylindrical Body Volume (in cc.) of Females With Various Diseases

(Calculated from data of Tables 11 and 13)

ORDER	GROUP	MEAN AGE OR AGE LIMITS (*yrs.*)	COMPUTED CYLINDRICAL BODY VOLUME (*cc.*)
1	*Cardiacs*	*54.05± .48*	*99586*
2	Gall bladder disease	43.57	96730
3	Nephritis and hypertension	33.50	90254
4	Asthma	37.72	89747
5	Pernicious Anemia	52.39	88709
6	*Non-cardiacs*	*49.59± .71*	*86531*
7	Gastric and duodenal ulcers	39.17	84595
8	Tuberculosis	54.62	81454

SITTING HEIGHT AND TRUNK LENGTH

The nephritis and hypertension group occupies first place for Sitting Height (Table 15) and second place for Trunk Length (Table 16). The asthma group and the cardiacs show the minimum mean values for these measurements. In general the differences are so small as to give doubtful significance to the fact that the order of the various groups is somewhat different for Sitting Height and for Trunk Length, when the series are compared to each other or with that for Stature. Both appear to be stable characters; the percentage increase of the first group in terms of the last is for Sitting Height, 2.4 percent and for Trunk Length 3.0 percent.

TABLE 15

Mean Sitting Height (in Centimeters) of Females With Various Diseases (Age data and references same as in Table 10)

ORDER	GROUP	MEAN SITTING HEIGHT (*cm.*)	*N*
1	Nephritis and hypertension	84.46	20
2	Tuberculosis	84.18	28
3	Gastric and duodenal ulcers	83.83	8
4	*Non-cardiacs*	*83.62± .42*	*37*
5	Gall bladder disease	83.46	30
6	Pernicious Anemia	82.78	19
7	*Cardiacs*	*82.72± .23*	*126*
8	Asthma	82.45	11

TABLE 16

Mean Trunk Length (in Centimeters) of Females With Various Diseases (Age data same as in Table 10, references same as in Table 13)

ORDER	GROUP	MEAN TRUNK LENGTH (*cm.*)	*N*
1	Gall bladder disease	55.47	30
2	Nephritis and hypertension	54.92	20
3	Gastric and duodenal ulcer	54.77	9
4	Pernicious Anemia	54.68	20
5	*Non-cardiacs*	*54.56± .35*	*37*
6	Tuberculosis	54.46	28
7	Asthma	53.95	11
8	*Cardiacs*	*53.87± .18*	*124*

For the Span (Table 17) the order is somewhat different than for Stature with which it is actually highly correlated. The intergroup differences are small though; between the first and last it is only 4.0 percent of the mean of the last. This is smaller than that observed for the Stature, which is influenced, undoubtedly, by the high average of the small Old American groups of age 59 and above.

TABLE 17

Mean Span (in Centimeters) of Females With Various Diseases

(Age data same as in Table 10, references same as in Table 13)

ORDER	GROUP	MEAN SPAN (*cm.*)	*N*
1	Nephritis and hypertension	162.08	19
2	Asthma	159.78	11
3	*Cardiacs*	*158.75± .44*	*124*
4	Tuberculosis	158.39	28
5	*Non-cardiacs*	*158.20± .84*	*36*
6	Pernicious Anemia	157.17	19
7	Gall bladder disease	156.87	31
8	Gastric and duodenal ulcer	155.79	11

HEAD DIMENSIONS

The mean measurements of Head Length, Breadth and Circumference are given in Tables 18, 19, and 20. There appears to be some correspondence in the relative positions of each group for both Head Length and Breadth but not for Head Circumference. One may say that the cholecystitis and peptic ulcer groups have the smallest dimensions while the asthma group and the cardiacs have the highest. In relation to the mean values of the lowest, the differences between the highest and lowest are for Head Length 7.2 percent, Head Breadth 6.9 percent, and Head Circumference 1.9 percent. The relatively low percentage found for the last character may be in part an expression of the ease and security in obtaining this measurement.

TABLE 18

Mean Head Length (in Centimeters) of Females With Various Diseases
(Age data and references same as in Table 10)

ORDER	GROUP	MEAN HEAD LENGTH (*cm.*)	*N*
1	Nephritis and hypertension	18.50	20
2	Asthma	18.48	11
3	*Cardiacs*	*18.36± .04*	*125*
4	Gall bladder disease	18.23	32
5	Tuberculosis	18.22	28
6	Gastric and duodenal ulcers	18.21	32
7	Pernicious Anemia	18.11	21
8	*Non-cardiacs*	*17.99± .09*	*37*
9	Peptic ulcers	17.40	12
10	Diabetes	17.31	52
11	Cholecystitis	17.25	37

TABLE 19

Mean Head Breadth (in Centimeters) of Females With Various Diseases
(Age data and references same as in Table 10)

ORDER	GROUP	MEAN HEAD BREADTH (*cm.*)	*N*
1	Pernicious Anemia	14.91	21
2	Gall bladder disease	14.88	32
3	*Cardiacs*	*14.88± .04*	*125*
4	Asthma	14.78	11
5	Nephritis and hypertension	14.65	19
6	Gastric and duodenal ulcers	14.64	12
7	Tuberculosis	14.50	28
8	Diabetes	14.34	52
9	*Non-cardiacs*	*14.28± .08*	*37*
10	Cholecystitis	14.23	37
11	Peptic ulcers	13.95	12

TABLE 20

Mean Head Circumference (in Centimeters) of Females With Various Diseases

(Age data and references same as in Table 10)

ORDER	GROUP	MEAN HEAD CIRCUMFERENCE (*cm.*)	*N*
1	Gastric and duodenal ulcers	55.06	7
2	Asthma	54.87	3
3	*Cardiacs*	*54.84± .09*	*123*
4	Nephritis and hypertension	54.70	6
5	*Non-cardiacs*	*54.58± .19*	*37*
6	Gall bladder disease	54.12	29
7	Tuberculosis	54.04	26

BIACROMIAL AND BIILIAC DIAMETERS

For the Biacromial Diameter (Table 21) the order of the groups is essentially the same as that for the Weight, except for the peptic ulcer patients. This group together with the nephritis and hypertension, gall bladder disease, asthma and

TABLE 21

Mean Biacromial Breadth (in Centimeters) of Females With Various Diseases

(Age data same as in Table 10, and references same as in Table 13)

ORDER	GROUP	MEAN BIACROMIAL BREADTH (*cm.*)	*N*
1	Peptic ulcers	35.20	12
2	Nephritis and hypertension	35.12	20
3	*Cardiacs*	*34.84± .12*	*125*
4	Asthma	34.77	11
5	Gall bladder disease	34.49	30
6	Cholecystitis	33.92	37
7	*Non-cardiacs*	*33.86± .22*	*37*
8	Diabetes	33.77	52
9	Gastric and duodenal ulcers	33.75	11
10	Tuberculosis	33.61	28
11	Pernicious Anemia	33.32	18

TABLE 22

Mean Biiliac Breadth (in Centimeters) of Females With Various Diseases

(Age data same as in Table 10, and references same as in Table 13)

ORDER	GROUP	MEAN BIILIAC BREADTH (*cm.*)	*N*
1	*Cardiacs*	*29.44± .14*	*123*
2	Pernicious Anemia	29.35	18
3	Gall bladder disease	29.33	30
4	Gastric and duodenal ulcers	28.65	11
5	Tuberculosis	28.52	27
6	Nephritis and hypertension	28.46	20
7	Asthma	28.20	11
8	*Non-cardiacs*	*28.03± .25*	*37*

cardiac groups have the highest means. The difference between the highest and lowest of the 11 means is 5.6 percent of the latter. Table 22 which gives the comparative data for the Biiliac Diameter shows a rather different distribution than expected. This should deserve further investigation. The cardiacs and non-cardiacs occupy first and last place respectively; the mean of the former is superior to that of the latter by 5.0 percent. The order of the other groups is practically the reverse of that noted for Weight and Biacromial Diameter; the pernicious anemia group last for these dimensions takes second place, etc.

CHEST DEPTH

The order of the groups according to mean Chest Depth (Table 23) is in fair agreement with that of Weight and Chest Circumference. The gall bladder disease group and the cardiacs have the deepest chests, the non-cardiacs and the tuberculosis group the shallowest. The position of the pernicious anemia group is somewhat unexpected. The intergroup difference appears large: 16.4 percent.

NECK GIRTH

The cardiacs and gall bladder disease group have the highest mean values, peptic ulcer and pernicious anemia the lowest (Table 24). The cardiacs show an increase of 11.0 percent with respect to the mean of the pernicious anemia group.

TABLE 23

Mean Chest Depth (in Centimeters) of Females With Various Diseases
(Age data same as in Table 10, and references same as in Table 13)

ORDER	GROUP	MEAN CHEST DEPTH (*cm.*)	*N*
1	Gall bladder disease	21.60	31
2	*Cardiacs*	*21.03± .14*	*125*
3	Pernicious Anemia	20.91	17
4	Asthma	20.25	11
5	Nephritis and hypertension	19.98	20
6	Gastric and duodenal ulcers	19.55	11
7	*Non-cardiacs*	*18.73± .28*	*37*
8	Tuberculosis	18.55	28

TABLE 24

Mean Neck Girth (in Centimeters) of Females With Various Diseases
(Age data and references same as in Table 10)

ORDER	GROUP	MEAN NECK GIRTH (*cm.*)	*N*
1	*Cardiacs*	*34.45± .18*	*123*
2	Gall bladder disease	34.28	31
3	Diabetes	32.93	52
4	Cholecystitis	32.43	37
5	Asthma	32.39	11
6	Gastric and duodenal ulcers	32.34	11
7	*Non-cardiacs*	*32.33± .23*	*37*
8	Nephritis and hypertension	31.99	20
9	Tuberculosis	31.94	28
10	Peptic ulcers	31.79	12
11	Pernicious Anemia	31.03	17

EAR LENGTH AND EAR BREADTH

The cardiacs appear to have the longest and widest ears, the tuberculosis group the smallest (Tables 25 and 26). The difference between the highest and lowest mean, in terms of the latter, is 11.4 percent for Ear Length and 8.6 percent for Ear Breadth.

In summary, this comparison of groups with different diseases shows that the absolute and relative overweight of the cardiacs of this material associates this group, somatologically, to the gall bladder disease, asthma, and nephritis and hypertension groups of Draper, and the cholecystitis and diabetes groups of Feigenbaum and Howat; they are all superior to the non-cardiacs and the tuberculosis, pernicious anemia, gastric and duodenal ulcer and peptic ulcer groups. This same position is maintained in general for all the horizontal dimensions. In view of the high correlation between these and Body Weight, the discrepancies observed may be regarded as due to any of the many factors not taken into consideration here.

TABLE 25

Mean Ear Length (in Centimeters) of Females With Various Diseases

(Age data and references same as in Table 10)

ORDER	GROUP	MEAN EAR LENGTH (*cm.*)	*N*
1	Diabetes	6.45	52
2	*Cardiacs*	*6.41± .03*	*123*
3	Pernicious Anemia	6.27	23
4	*Non-cardiacs*	*6.22± .05*	*37*
5	Gall bladder disease	6.21	32
6	Cholecystitis	6.13	37
7	Nephritis and hypertension	6.06	11
8	Asthma	6.04	11
9	Peptic ulcers	5.95	12
10	Gastric and duodenal ulcers	5.84	12
11	Tuberculosis	5.79	28

TABLE 26

Mean Ear Breadth (in Centimeters) of Females With Various Diseases (Age data and references same as in Table 10)

ORDER	GROUP	MEAN EAR BREADTH (*cm.*)	*N*
1	Gall bladder disease	3.43	32
2	*Cardiacs*	*3.43± .02*	*123*
3	Asthma	3.36	11
4	*Non-cardiacs*	*3.22± .05*	*37*
5	Pernicious Anemia	3.21	23
6	Nephritis and hypertension	3.21	18
7	Gastric and duodenal ulcers	3.20	12
8	Tuberculosis	3.16	28

BODY PROPORTIONS

The direct relationship between certain dimensions of the body may be measured by any number of simple indices or ratios (4). A few of these have been computed and are presented in Table 27. In each case the index (ratio or product) was separately calculated for each single individual in both cardiac and non-cardiac groups. Frequency distributions were then made and the biometric constants of Table 27 calculated in the usual way.

From Table 27 the following facts are observed.

1. The ratios involving chest girth, biacromial breadth, or biiliac breadth as a numerator and stature or trunk length as a denominator have higher mean values for the cardiacs than for the non-cardiacs in this material. This superiority of the cardiacs is statistically significant. All these indices mentioned indicate the greater apparent stockiness of build of the cardiacs.

2. On the average the non-cardiacs apparently possess relatively shorter legs and longer trunk than the cardiacs as shown by the mean sitting height/stature ratio which is significantly higher in the first, and by the trunk length/stature which is very probably significantly higher in the non-cardiacs.

TABLE 27

Anthropometric Indices for Cardiacs and Non-cardiacs

VARIABLE	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
$100 \frac{\text{Chest girth (rest.)}}{\text{Stature}}$								
Cardiacs	126	58.14 ± .38	58.11 ± .48	6.35 ± .27	10.92 ± .47	42.6	79.3	36.7
Non-cardiacs	37	54.39 ± .74	53.57 ± .93	6.66 ± .52	12.24 ± .97	41.6	75.6	34.0
$100 \frac{\text{Sitting height}}{\text{Stature}}$								
Cardiacs	126	52.79 ± .08	52.91 ± .10	1.31 ± .06	2.48 ± .11	47.5	56.0	8.5
Non-cardiacs	37	53.45 ± .17	53.39 ± .21	1.49 ± .12	2.79 ± .22	47.2	56.7	9.5
$100 \frac{\text{Trunk length}}{\text{Stature}}$								
Cardiacs	126	34.37 ± .08	34.56 ± .10	1.32 ± .06	3.84 ± .16	27.0	37.6	10.6
Non-cardiacs	37	34.88 ± .17	34.92 ± .21	1.57 ± .12	4.50 ± .35	28.0	37.7	9.7

TABLE 27—*Continued*

VARIABLE	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
$100 \frac{\text{Biacromial breadth}}{\text{Stature}}$								
Cardiacs	125	22.22 ± .07	22.35 ± .09	1.21 ± .05	5.45 ± .23	18.9	26.1	7.2
Non-cardiacs	37	21.50 ± .11	21.70 ± .14	1.03 ± .08	4.79 ± .38	19.3	23.9	4.6
$100 \frac{\text{Biiliac breadth}}{\text{Stature}}$								
Cardiacs	123	18.80 ± .08	18.71 ± .10	1.38 ± .06	7.34 ± .32	14.3	22.3	8.0
Non-cardiacs	37	17.80 ± .20	17.60 ± .25	1.78 ± .14	10.00 ± .79	13.8	22.9	9.1
$100 \frac{\text{Biacromial breadth}}{\text{Trunk length}}$								
Cardiacs	123	64.66 ± .24	64.41 ± .30	3.88 ± .17	6.00 ± .26	57.7	80.0	22.3
Non-cardiacs	37	61.96 ± .47	61.67 ± .59	4.32 ± .34	6.97 ± .55	55.2	70.4	15.2
$\frac{\text{Trunk length} \times \text{Chest depth} \times \text{Biacro. breadth}}{1000}$								
Cardiacs	123	39.86 ± .39	39.69 ± .49	6.35 ± .27	15.93 ± .70	25.9	57.9	32.0
Non-cardiacs	37	34.12 ± .57	35.00 ± .71	5.14 ± .40	15.06 ± 1.21	23.2	47.1	23.9

$100 \frac{\text{Chest girth (inspiration)}}{\text{Chest girth (rest.)}}$								
Cardiacs	125	102.32 ± .07	102.31 ± .09	1.16 ± .05	1.13 ± .05	100.1	106.5	6.4
Non-cardiacs	36	102.58 ± .14	102.50 ± .18	1.26 ± .10	1.23 ± .10	100.6	106.4	5.8
$100 \frac{\text{Chest girth (expiration)}}{\text{Chest girth (rest.)}}$								
Cardiacs	125	98.33 ± .06	98.45 ± .08	1.01 ± .04	1.03 ± .04	94.1	99.9	5.8
Non-cardiacs	36	98.19 ± .11	98.39 ± .14	.96 ± .08	.98 ± .08	95.5	99.7	4.2
$100 \frac{\text{Chest expansion (Insp. girth—exp. girth)}}{\text{Chest girth (expiration)}}$								
Cardiacs	125	4.02 ± .11	3.90 ± .14	1.84 ± .08	45.77 ± 2.33	.10	8.49	8.39
Non-cardiacs	36	4.53 ± .22	4.30 ± .28	1.97 ± .16	43.49 ± 4.06	1.35	9.33	7.98
Cephalic index								
Cardiacs	125	81.26 ± .22	81.10 ± .28	3.66 ± .16	4.50 ± .19	72.4	90.1	18.3
Non-cardiac	37	79.85 ± .40	79.57 ± .50	3.61 ± .28	4.52 ± .36	75.1	90.9	15.8

3. The diametral trunk product, devised to give an indication of the total bulk or volume of the trunk, has a definitely higher mean value in the cardiacs than in the non-cardiacs.

4. None of the chest indices is significantly different in the two groups.

5. The means of the cephalic index show that the cardiacs have relatively wider heads than the non-cardiacs in this material. The differences are statistically significant and in terms of the standard classification (24) the cardiacs as a group are brachycephalic while the non-cardiacs are mesocephalic.

The percentage distribution of the individuals of each group in the different classes is as follows:

Cephalic Index Limits		*Percentage frequency in* *Cardiacs*	*Non-cardiacs*
Ultradolichocephalic	(61-65.99)	0	0
Hyperdolichocephalic	(66-70.99)	0	0
Dolichocephalic	(71-75.99)	4.8	10.8
Mesocephalic	(76-80.99)	44.8	56.8
Brachycephalic	(81-85.99)	40.8	27.0
Hyperbrachycephalic	(86-90.99)	9.6	5.4
Ultrabrachycephalic	(91-95.99)	0	0

Draper's data and those of Feigenbaum and Howat give the following mean values for the cephalic index in females. These have been calculated by the author from the mean absolute head dimensions given by them.

Nephritis and hypertension .....79.2 (Mesocephalic)
Tuberculosis .....79.6 (Mesocephalic)
Asthma .....80.0 (Mesocephalic)
Peptic ulcer .....80.2 (Mesocephalic)
Gastric and duodenal ulcers .....80.4 (Mesocephalic)
Gall bladder diseases .....81.6 (Brachycephalic)
Pernicious anemia .....82.3 (Brachycephalic)
Cholecystitis .....82.5 (Brachycephalic)
Diabetes .....82.8 (Brachycephalic)

The actual numerical values for these groups are comparable with those of this material. The same can be said for the mean cephalic index of Hrdlička's Laboratory Old Americans (p. 164) which is 79.40.

6. The absolute dispersion (standard deviation) is greatest for the chest girth/stature index and diametral trunk product, least for the biacromial breadth/stature index and those relating the chest girths to each other. The cardiacs show a greater absolute variability than the non-cardiacs, very probably significant for the diametral trunk products. The non-cardiacs have a larger standard deviation (probable error of mean difference > 2.5) than the cardiacs for the biiliac breadth/stature index.

7. The coefficient of variation, relative variability, for the biiliac breadth/stature ratio is also significantly higher in the non-cardiacs than the cardiacs. The highest value of this coefficient is found for the chest expansion index and the lowest for ratios relating the chest girths to each other directly.

In a striking manner these data confirm the fact that the cardiacs compared to the non-cardiacs show a preponderance of the horizontal dimensions. In this respect they are also in close agreement with the findings of Pearl and Ciocco but show however a relatively greater divergence between cardiacs and non-cardiacs. The sitting height index and trunk length index which the above authors found superior in the cardiacs is here instead superior in the non-cardiacs. It is of interest to note that in the females the difference in chest expansion index between cardiacs and non-cardiacs is not so marked as in the males of Pearl and Ciocco. The mean value of this index for the females when compared to that for males is 37 percent lower in cardiacs and 45 percent lower in non-cardiacs, thus presenting a characteristic sex difference.

OTHER SOMATIC CHARACTERS

The differences between cardiacs and non-cardiacs which result from the comparative anthropometric data can be further indicated by a brief survey of some of the descriptive (not measured) somatic characters recorded at the examination.

A fourfold classification of the degree of adiposity was used and in Table 28 are given the absolute and relative frequencies as observed for the body as a whole, the neck, breasts, abdomen, hips and extremities. For the body only 11.2 percent of the cardiacs were found to have

TABLE 28

Degree of Adiposis

PART OF BODY	AMOUNT OF FAT								N
	BELOW AVERAGE		AVERAGE		ABOVE AVERAGE		EXCESSIVE		
	Absolute number	Percent	Absolute number	Percent	Absolute number	Percent	Absolute number	Percent	
Body as a whole									
Cardiacs	14	11.2	38	30.2	53	42.4	20	16.0	125
Non-cardiacs	15	40.6	12	32.4	9	24.3	1	2.7	37
Neck									
Cardiacs	14	11.2	50	40.0	56	44.8	5	4.0	125
Non-cardiacs	14	37.8	14	37.8	9	24.3	..	...	37
Breasts									
Cardiacs	14	11.3	44	35.5	55	44.3	11	8.9	124
Non-cardiacs	10	27.8	17	47.2	9	25.0	..	...	36
Abdomen									
Cardiacs	11	8.8	28	22.4	49	39.4	37	29.6	125
Non-cardiacs	8	21.6	14	37.8	14	37.8	1	2.7	37
Hips									
Cardiacs	13	10.4	61	48.8	40	32.0	11	8.8	125
Non-cardiacs	11	29.7	16	43.2	10	27.0	..	...	37
Extremities									
Cardiacs	18	14.4	49	39.2	51	40.8	7	5.6	125
Non-cardiacs	13	35.1	16	43.2	8	21.6	..	...	37

an amount of fat below average, while 40.6 percent of the non-cardiacs were so classified. The positions are reversed for the categories of above average and excessive fat. Practically the same relationship is found for the separate parts of the body as mentioned. For each the difference in relative distribution between cardiacs and non-cardiacs is statistically significant when tested by the chi-square criterion. The divergence is most marked for the abdomen.

Taking cardiacs and non-cardiacs separately let us compare for each group the relative distribution of fat over the divers parts of the body with that of the body as a whole. As expected, the abdomen is the most favored location for deposit of fat, the incidence of women with above average and excessive amount of fat over the abdomen is higher than those with the same amount over the whole body. This

TABLE 29

Chest Shape, Costal Margins, and Movement of Chest Wall

	CARDIACS		NON-CARDIACS	
	Absolute numbers	Percent	Absolute numbers	Percent
Chest shape				
Normal	71	57.7	23	63.9
Flat	8	6.5	10	27.8
Chicken-breasted	3	2.4	..	...
Barrel-shaped	41	33.3	3	8.3
Total	123	99.9	36	100.0
Costal margins				
Normal	67	53.2	31	86.1
Flaring	59	46.8	5	13.9
Total	126	100.0	36	100.0
Movement of Chest Wall				
Right equals left	119	94.4	32	91.4
Right more	4	3.2	2	5.7
Right less	3	2.4	1	2.9
Total	126	100.0	35	100.0

is true for both cardiacs and non-cardiacs. Cardiacs classified as having for the body in general above average and excessive fat may have less adiposis at the neck, hip or extremities. For the breasts, the percentage of cardiacs in the different categories is practically the same as that for the body in general. The non-cardiacs have a somewhat greater degree of adiposis on the breasts, abdomen and hips than on the neck and extremities. The relative distribution is practically the same as for the whole body. From these observations it follows that uniformity in the deposition of fat in the various parts of the body is not to be frequently expected. This again illustrates the necessity of numerical measurements or more precise qualitative descriptions in the somatological classification of individuals.

The absolute and relative frequencies of the various chest shapes, types of costal margins, and particulars of the chest movement are given in Table 29. Chests normal in shape are found in almost equal percentage among cardiacs and non-cardiacs. But, the cardiacs have a relatively higher percentage of the barrel-shaped type and the non-cardiacs of the flat shape. This difference in form of chest is further emphasized by the significantly higher proportions of individuals with flaring costal margins among the cardiacs. With regard to the bilateral symmetry of movement of the chest, over 90 percent of both cardiacs and non-cardiacs show no abnormality.

In summary, these supplementary descriptive data bring out in greater relief the fact that the dissimilarity between cardiacs and non-cardiacs lies chiefly in the relative overfatness of the former, especially at the abdomen, accompanied by evidently wider costal angle and flaring costal margins.

SOMATOLOGICAL TYPES

The classical threefold division of bodily types is not sharply delimited nor defined in precise numerical terms. This has been pointed out by various authors and discussed elsewhere (4, 15). Nevertheless, it is a useful way of classifying individuals and prestige has been given it by the number of physiological and pathological characteristics found related to the different types.

The present material was typed by careful study of the nude patients at the time of examination and their photographs made in the manner described in (17). The judgements, for trunk and limbs separately, were recorded on the 13 point dual scale used in this laboratory. On these

TABLE 30

Distribution of Cardiacs and Non-cardiacs According to Bodily Habitus

TYPE SCALE NUMBERS	TRUNK		LIMBS	
	Cardiacs	Non-cardiacs	Cardiacs	Non-cardiacs
0	..	1	1	2
1	2	4	3	3
2	2	1	1	0
3	10	4	8	4
4	6	3	10	3
5	15	10	18	6
6	18	7	27	11
7	21	1	19	3
8	18	2	7	0
9	2	1	7	2
10	7	1	12	1
11	14	1	6	1
12	11	1	7	1
Total	126	37	126	37
Mean scale position...	7.71 ± .17	5.55 ± .30	7.19 ± .16	5.57 ± .30
Standard deviation	2.80 ± .12	2.67 ± .21	2.66 ± .11	2.73 ± .21

scales 0 represents the most extreme asthenic habitus and 12 the most extreme pyknic habitus, while 6 denotes the perfect intermediate (athletic of Kretschmer) bodily habitus.

The resulting distributions for this material are shown in Table 30. Representatives of practically all the scale types are found among both cardiacs and non-cardiacs. Consequently the range embraces the whole 13 points. However the cardiacs have a greater concentration of individuals towards the pyknic end of the scale which affects the mean scale position.

The difference between the means is, for the trunk more than 6 times its probable error, and for the limbs more than 4 times. Assuming that types 0 to 3 are asthenic, 4 to 8 intermediate, and 9 to 12 pyknic, the percentage distribution of the three somatological types is shown in Table 31. As expected the intermediates are equally frequent in both groups. But, the percentage of pyknics among the cardiacs is about 2½ times that of the asthenics. This is the reverse of what is ob-

served among the non-cardiacs. The differences in distribution are very probably significant, statistically. It means only that in this sample there are relatively more pyknics and fewer asthenics among the cardiacs compared to the non-cardiacs.

TABLE 31

Percentages of Somatological Types in Cardiacs and Non-cardiacs

BODILY HABITUS	TRUNK		LIMBS	
	Cardiacs	Non-cardiacs	Cardiacs	Non-cardiacs
Asthenic (Type scale Nos. 0-3)	11.1±1.9	27.0±4.9	10.3±1.8	24.3±4.8
Intermediate (Type scale Nos. 4-8)	61.9±3.1	62.2±5.4	64.3±2.9	62.2±5.4
Pyknic (Type scale Nos. 9-12)	27.0±2.7	10.8±3.4	25.4±2.6	13.5±3.8

From the two preceding tables it is evident that the classification of trunk and limbs is not always the same. Dysplasia in a greater or less degree is often observed, either congenital, or as the effect of age when there is a tendency for fat to accumulate more on the trunk than on the extremities. As a convenient numerical index of dysplasia, in this laboratory it is the custom to use the differences (regardless of sign) between the scale numbers for the trunk and limbs in the same individual. The distribution of these differences for the present sample is shown in Table 32. The mean degree of dysplasia for the cardiacs is 2.03 ± .09 and for the non-cardiacs it is 1.53 ± .11. The difference between the means is 3.6 times its probable error. If we take degrees of dysplasia 0, 1, 2 as indicative of substantial euplasia and 3, 4, etc. as indicative of substantial dysplasia, it appears that among the cardiacs there are 80.2 percent euplastics and 19.8 percent dysplastics as against 91.8 percent euplastics and 8.2 percent dysplastics among the non-cardiacs. This difference is not statistically significant, but there is an evident tendency of greater dysplasia among the cardiacs than among the non-cardiacs.

TABLE 32

Degree of Dysplasia

(Difference between trunk and limb type scale number)

DEGREE OF DYSPLASIA	CARDIACS	NON-CARDIACS
0	37	13
1	34	15
2	30	6
3	11	2
4	7	1
5	5	..
6	1	..
7	1	..
Totals	126	37

Another way of approaching this problem is to consider the relative distribution of pure somatological types. These have been defined (16) as follows:

Pure asthenic *Type scale number*		*Pure intermediate* *Type scale number*		*Pure pyknic* *Type scale number*	
Trunk	*Limbs*	*Trunk*	*Limbs*	*Trunk*	*Limbs*
0	with 0, 1, or 2	4	with 4, 5, or 6	9	with 9, 10, or 11
1	with 0, 1, 2, or 3	5	with 4, 5, 6, or 7	10	with 9, 10, 11, or 12
2	with 0, 1, 2, or 3	6	with 4, 5, 6, 7, or 8	11	with 9, 10, 11, or 12
3	with 1, 2, or 3	7	with 5, 6, 7, or 8	12	with 10, 11, or 12
		8	with 6, 7, or 8		

The absolute and relative distributions for the two groups are given in Table 33. The non-cardiacs of the present material include more pure somatological types than the cardiacs, by some 7. 6 percent. This reflects the already noted tendency towards greater frequency of dysplasia among the cardiacs. But the most interesting thing brought out by Table 33 is the higher proportion of pure pyknics in the cardiac group and pure asthenics in the non-cardiac group.

It is justifiable to combine Table 33 with the corresponding table for the males of the same material (Table 25 of Pearl and Ciocco (16)). When this is done we have the results shown in Table 34.

TABLE 33

Numbers and Percentages of Pure Somatological Types in Cardiacs and Non-cardiacs

TYPES	CARDIACS		NON-CARDIACS	
	N	Percentages in whole group (126)	*N*	Percentages in whole group (37)
Pure asthenics	10	7.9	8	21.6
Pure intermediates	61	48.4	20	54.1
Pure pyknics	25	19.9	3	8.1
Totals	96	76.2	31	83.8

TABLE 34

Pure Somatological Types in Cardiacs and Non-cardiacs, Males and Females Combined

TYPES	CARDIACS		NON-CARDIACS	
	N	Percentages in whole group (213)	*N*	Percentages in whole group (87)
Pure asthenic	17	7.6	14	16.1
Pure intermediate	99	44.4	47	54.0
Pure pyknic	28	12.6	5	5.7
Totals	144	64.6	66	75.8

TABLE 35

Bodily Dimensions of Asthenics (Trunk Type Scale Numbers 0-3)

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Weight (kg.)								
Cardiacs	13	54.23 ± 1.72	53.00 ± 2.16	9.17 ±1.21	16.91 ± 2.30	42.0	74.0	32.0
Non-cardiacs	10	47.00 ± 1.28	46.67 ± 1.60	6.00 ± .90	12.77 ± 1.96	37.3	57.8	20.5
Stature (cm.)								
Cardiacs	14	156.07 ± .99	161.25 ± 1.24	5.49 ± .70	3.52 ± .45	149.4	168.7	19.3
Non-cardiacs	10	161.50 ± 1.49	162.50 ± 1.87	7.00 ±1.06	4.33 ± .65	146.7	170.0	23.3
Chest girth (rest) (cm.)								
Cardiacs	14	80.00 ± 1.01	80.00 ± 1.27	5.59 ± .71	7.49 ± .90	69.5	89.6	20.1
Non-cardiacs	9	76.94 ± 1.24	76.88 ± 1.55	5.50 ± .87	7.15 ± 1.14	67.9	85.5	17.6

Table 34 shows with the utmost clarity that in this material the males and females are in substantial agreement relative to the distribution of somatological types in cardiacs and non-cardiacs. Furthermore there can be no doubt about the greater tendency towards dysplasia in the cardiacs (since the non-cardiacs include, as a whole group, 11.2 percent more pure somatological types than the cardiacs); or that the cardiacs include a higher proportion of pure pyknics and the non-cardiacs a higher proportion of pure asthenics.

A somewhat higher percentage of pyknics in this material cannot sufficiently account for the marked somatic differences between cardiacs and non-cardiacs. It is therefore necessary to investigate whether between cardiacs and non-cardiacs of each somatological habitus important anthropometric characters also differ. Tables 35, 36, and 37 give the biometric constants for weight, stature and chest girth at rest of cardiac and non-cardiac asthenics, intermediates and pyknics. The numbers in each group with the exception of the intermediates are small and consequently the probable errors are large. A definite conclusion cannot therefore be reached for all dimensions but the evident trends are of interest.

The following points are to be noted:

1. As expected mean body weight and chest girths increase and mean stature decreases as one passes from asthenics to pyknics.

2. The cardiacs are, in every case, on the average heavier than the non-cardiacs with the same somatic habitus. The differences are statistically significant (> 3 times probable error of difference) for asthenics and intermediates, very probably significant (> 2.5) for pyknics.

3. The non-cardiac asthenics are significantly taller than the cardiac asthenics. The differences between the two groups are not statistically important for intermediates and pyknics.

4. For each somatic habitus the cardiacs are superior in mean chest girth. The differences are not statistically important except for the intermediates. For these the difference is very probably significant. The trend here shown is unmistakable and its meaning definite when one remembers the high correlation between chest girth and weight.

From the above results the superiority of the cardiacs in weight and correlated horizontal dimensions over the non-cardiacs is re-emphasized. It is apparently independent of somatic habitus.

TABLE 36

Bodily Dimensions of Intermediates (Trunk Type Scale Numbers 4-8)

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Weight (kg.)								
Cardiacs	71	66.15 ± .99	65.40 ± 1.24	12.39 ± .70	18.73 ± 1.10	35.0	96.3	61.3
Non-cardiacs	20	59.50 ± 1.47	57.27 ± 1.84	9.73 ±1.04	16.35 ± 1.79	44.0	84.0	40.0
Stature (cm.)								
Cardiacs	78	156.86 ± .48	157.50 ± .60	6.33 ± .34	4.04 ± .34	138.4	169.5	31.1
Non-cardiacs	23	155.55 ± .65	155.28 ± .81	4.60 ± .46	2.96 ± .29	146.1	167.9	21.8
Chest girth (rest) (cm.)								
Cardiacs	77	89.19 ± .54	89.14 ± .68	7.02 ± .38	7.87 ± .43	77.0	103.5	26.5
Non-cardiacs	23	86.42 ± .84	86.07 ± 1.05	5.98 ± .59	6.92 ± .69	75.0	97.0	22.0

TABLE 37

Bodily Dimensions of Pyknics (Trunk Type Scale Numbers, 9-12)

CHARACTER	*N*	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM OBS.	MAXIMUM OBS.	RANGE
Weight (kg.)								
Cardiacs	30	82.00 ± 1.83	80.00 ± 2.29	14.87 ±1.29	18.13 ± 1.63	58.6	116.0	57.4
Non-cardiacs	4	70.00 ± 3.77	70.00 ± 4.73	11.18 ±2.67	15.97 ± 3.90	52.2	84.6	32.4
Stature (cm.)								
Cardiacs	34	153.88 ± .85	154.00 ± 1.07	7.34 ± .52	4.77 ± .39	126.0	166.2	40.2
Non-cardiacs	4	150.00 ± 4.54	155.00 ± 5.69	13.47 ±3.21	8.98 ± 2.16	127.6	166.0	38.4
Chest girth (rest) (cm.)								
Cardiacs	34	99.26 ± 1.21	100.00 ± 1.52	10.43 ± .85	10.51 ± .87	61.5	122.0	60.5
Non-cardiacs	4	96.25 ± .73	96.67 ± .91	2.17 ± .52	2.25 ± .54	94.5	98.0	3.5

SUMMARY AND DISCUSSION

The author has compared two groups of white females whose ages range between 40 and 69 years. The first of these groups, the cardiacs is composed of women having some form of heart lesion, mild or grave as the case might be. The individuals of the other group, the non-cardiacs, are free from all signs and symptoms of heart disease. The cardiacs have a high incidence of hypertension and arteriosclerosis; and, compared to the non-cardiacs, a higher incidence of diagnosed nephritis and diabetes, and typhoid fever, scarlet fever and pneumonia in their past medical history; they complain more often of chronic constipation. The heart of the cardiacs has a greater mean transverse diameter than the non-cardiacs and is apparently placed more horizontal in position. The non-cardiacs on the other hand, have a higher incidence of syphilis, malignancies and diseases of the alimentary tract.

There is essentially no difference between cardiacs and non-cardiacs in stature, auditory canal height, suprasternal notch height, lower costal margin height, sitting height, trunk length, span and head girth.

The cardiacs show substantial and significant superiority in weight, biacromial, biiliac and greatest hip breadths, chest depths, chest girths, umbilicus girth, head length and breadth, ear length and breadth.

The cardiacs moreover are superior for all the anthropometric indices relating chest girth, biacromial and biiliac breadth to stature or trunk length.

Above average and excessive fat, especially at the abdomen, is observed relatively more frequently in the cardiacs than in the non-cardiacs. Flaring costal margins and barrel shaped chests are also relatively more frequent in cardiacs.

When compared to the non-cardiacs, the cardiacs show a lack of correlation between the variations in distance from the midline of the point of maximum impulse of the heart and stature, chest girth, umbilicus girth and the chest girth/stature index.

The intermediate habitus is preponderant in both groups but the pyknics are relatively more frequent in cardiacs than non-cardiacs. For each somatic habitus the mean weight and chest girth of the cardiacs is superior to that of the non-cardiacs.

The general conclusion that can be drawn from these data on women is that the cardiacs as a group are characterized by greater body weight associated with greater chest and especially greater umbilicus girths. The same was observed by Pearl and Ciocco (16) on men.

And here it is again to be emphasized that there is no *proof* that this relative overweight is an etiological factor in heart disease, nor is it apparently the consequence of a true innate constitutional difference between cardiacs and non-cardiacs.

However, many clinical studies on obesity have shown its close relation to cardio-vascular impairment (9, 12, 14). The hypothesis advanced by Pearl and Ciocco that the somatological differences may be due to accumulation of fat consequent upon relative overeating and lack of physical exercise is of interest in view of the reports of the above clinicians on the beneficial effect of restricted diet and consequent reduction of weight. These or any other clinical findings the author is not qualified to discuss. An important derivation should be emphasized and that is, that for the groups which have been compared there is a different mathematical relationship between the vertical and horizontal dimensions of the body and between these and certain dimensions of the heart. Therefore, from a somatological and anthropological standpoint it is of importance to determine more precisely what the variations are in the mathematical relationship between the primary axes of the body and between them and the different organs in order to understand the significance of these variations in health and disease.

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STUDIES ON CONSTITUTION, IV. ENDOCRINE ORGAN WEIGHTS AND SOMATOLOGICAL HABITUS TYPES[1]

BY RAYMOND PEARL, MARJORIE GOOCH, JOHN R. MINER, AND WALTER FREEMAN

THE PROBLEM

THE present paper is a continuation of an earlier study[2] on the relation of the endocrine organs to mental disease, particularly with reference to the different types of psychoses. The material used in the present study is the same as that used in the former investigation, and therefore the reader wishing to know more of the general characteristics of this material than is set forth here should consult the earlier paper. In the present study all psychosis types are pooled together (as is justified by the earlier results) and then reassorted according to somatological habitus types (often called "constitutional types"). The purpose of this procedure is *to determine how the endocrine organ weights individually, and the general endocrine system pattern, are differentiated quantitatively, if at all, in the asthenic, intermediate and pyknic body types.*

Obviously the desirable plan for the analysis would have been to make it for psychiatric and somatological types simultaneously. This

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[1] From the Department of Biology of the School of Hygiene and Public Health of The Johns Hopkins University. Three of the authors [R. P., J. R. M., and M. G.] are solely responsible for the analysis and discussion of the data in this paper and for its writing. The weights and measures were taken by W. Freeman in the course of routine post-mortem examinations, made in the Blackburn Laboratory of St. Elizabeth's Hospital, of persons dying in that institution, where for some years he was pathologist.

We are greatly indebted to the Josiah Macy, Jr. Foundation for a grant to the Department of Biology, to aid in the carrying out of this work.

[2] Pearl, R., M. Gooch, and W. Freeman. A biometric study of the endocrine organs in relation to mental disease. Part I. HUMAN BIOLOGY, Vol. 7, pp. 350-391, 1935; Part II. *Ibid*, Vol. 7, pp. 555-607, 1935.

would have given, keeping sex and color groups separate as is necessary, $4 \times 4 \times 2 \times 2 = 64$ sub-groups, each of such sort as male white asthenic paranoids, etc. Unfortunately, the total magnitude of the material available is not great enough to make so fine a subdivision feasible. The frequencies in the ultimate cells would be too small to give any definite results. Furthermore as the case turns out, this is not necessary because the earlier study[2] showed that there is no definite, orderly or significant differentiation in respect of endocrine weights between the several psychiatric types.

Consequently in this paper the biometric constants of variation in endocrine weights will be examined relative to four somatological habitus groups, as follows:

Asthenics,
Intermediates (called "Athletics" by Kretschmer),[3]
Pyknics,

and a fourth group made up of individuals not falling precisely into the so-called "pure" types, and called

Dysplastics.

The allocations of individuals to these habitus groups were made by W. Freeman at autopsy in every case (and are therefore his sole responsibility) on the basis of purely qualitative judgments reached from viewing the nude cadaver as a whole. The procedure which has become standard in the writer's laboratory[4] of typing trunk and limbs separately on a 13 point scale of quantitative estimation and expressing degree of dysplasticity as the numerical difference was not followed. A resulting consequence is that the proportion of individuals classed as dysplastics (*cf. infra*) in the present study differs somewhat from those reported in previous studies from this laboratory. However, no serious harm results from this, because what it really means is only that in the classification of the present material a standard for dysplasticity was maintained that was wholly qualitative rather than in some degree quantitative. In short, in the present study, we can feel quite con-

[2] Pearl [Constitution and Health, *London* (Kegan Paul, Trench, Trubner and Co.), 1933. Pp. 97] has given reasons for preferring "intermediate" to the somewhat ambiguous and question-begging term "athletic" to designate the habitus group falling between asthenics and pyknics.

[4] Pearl, R., A. C. Sutton, W. T. Howard, Jr., and Margaret Rioch. Studies on constitution, I. Methods. HUMAN BIOLOGY, Vol. 1, pp. 10-56, 1929.

fident about what the asthenic, intermediate, and pyknic categories included, and are left in doubt only as to exactly what the dysplastics were.

MATERIAL

The total material available for the present study comprises 1272 individuals, divided by race and sex as follows:

	Males	*Females*	*Totals*
White	549	224	773
Negro	297	202	499
Total	846	426	1272

These are all mentally diseased persons, and all the records were taken at autopsy. The significance of these facts, and the caution they make necessary in drawing conclusions from biometric data derived from the material have already been discussed at length and emphasized in the earlier study,[2] and must be regarded as applying with equal force here, except that in the present study we shall be under no logical compulsion to compare our data with those from persons not mentally diseased. This is a real gain, because it frees us of the difficulties inherent in the scarcity of so-called "normal" data for endocrine organ weights.

TABLE 1

Absolute and Relative Distributions of Somatological Types

SOMATOLOGICAL TYPES	WHITE MALES		WHITE FEMALES		NEGRO MALES		NEGRO FEMALES		TOTALS	
	N	Percent	*N*	Percent	*N*	Percent	*N*	Percent	*N*	Percent
Asthenics	184	33.5	81	36.2	99	33.3	55	27.2	419	32.9
Intermediates ...	196	35.7	60	26.8	133	44.8	86	42.6	475	37.3
Pyknics	85	15.5	45	20.1	31	10.4	35	17.3	196	15.4
Dysplastics	84	15.3	38	16.9	34	11.5	26	12.9	182	14.3
Totals	549	100	224	100	297	100	202	100	1272	99.9

The absolute and relative distributions of the patients by habitus types, sex and race are shown in Table 1.

With this general conspectus of the material in hand attention may be turned to the detailed discussion of specific points.

AGE

Table 2 presents the standard biometric constants for the ages of the individuals composing the several somatological habitus groups.

There is obvious throughout Table 2 a definite trend of mean and median ages among the three "pure" habitus types. Without exception the intermediates exhibit higher mean and median ages at death than the asthenics, and with one exception (white females) the pyknics died at mean and median ages greater than those exhibited by the intermediates. In interpreting the meaning of this trend it would be rash to conclude forthwith that the lateral growth habitus as distinguished from the longitudinal (*cf.* Pearl[3]) is *per se* conducive to longevity. The matter is certainly more complicated. In the first place it has been noted generally in constitutional studies on the *living* that the mean age tends to increase as one passes from the asthenic through the intermediate to the pyknic group. This is usually interpreted to mean nothing more than the combined effect of two sets of causes; namely (a) the well-known tendency for the human frame, statistically speaking, to store more fat and get plumper and rounder with advancing years after early adulthood, this tendency being mainly if not entirely due to a steady lessening of physical exercise with advancing years without any quantitatively corresponding reduction in the amount of calory content of the food intake, and (b) the fact that somatological habitus typing as usually carried out is a matter of purely qualitative judgment, one consequence of which is that it is extremely difficult to keep from putting any fat persons into the pyknic class straight away, without stopping to examine carefully whether the appearance presented is due to a true constitutional pyknic habitus, or only to relative obesity of nutritional origin.

A thorough and scientifically penetrating analysis of the relation of longevity to somatological types, freed from the conflicting testimony of nutritional and endocrine adiposity or excessive "slimming," has yet to be made. In fact there does not appear to exist at the present time any adequate body of material upon which to base such an analysis. The experience of life insurance companies teaches that excess adiposity

TABLE 2

Biometric Constants for Age

	ASTHENICS	INTERMEDIATES	PYKNICS	DYSPLASTICS
White Males ..N	184	196	85	84
Mean .....yrs.	55.11±0.86	58.27±0.80	62.41±1.04	60.71±1.25
Median ....yrs.	54.55±1.08	58.65±1.01	61.47±1.30	63.81±1.56
S. D. .....yrs.	17.32±0.61	16.68±0.57	14.15±0.73	16.92±0.88
C. V. ..percent	31.43±1.21	28.62±1.05	22.68±1.23	27.87±1.56
Range .....yrs.	22-97	20-93	35-93	12-85
White Females N	81	60	45	38
Mean .....yrs.	62.90±1.36	68.00±1.26	65.67±1.15	60.79±1.94
Median ....yrs.	67.31±1.71	70.00±1.59	66.33±1.44	63.00±2.43
S. D. .....yrs.	18.17±0.96	14.53±0.89	11.43±0.81	17.72±1.37
C. V. ..percent	28.89±1.65	21.36±1.37	19.90±1.47	29.14±2.44
Range .....yrs.	19-91	33-92	32-86	16-91
Negro Males ..N	99	133	31	34
Mean .....yrs.	48.13±1.21	57.33±0.89	58.23±1.52	51.47±2.49
Median ....yrs.	43.25±1.52	56.82±1.12	58.64±1.90	51.67±3.12
S. D. .....yrs.	17.90±0.86	15.26±0.63	12.54±1.07	21.54±1.76
C. V. ..percent	37.20±2.01	26.62±1.18	21.54±1.93	41.85±3.98
Range .....yrs.	21-94	24-97	31-84	15-94
Negro Females N	55	86	35	26
Mean .....yrs.	52.64±1.71	59.65±1.16	66.14±1.70	55.00±3.03
Median ....yrs.	53.50±2.15	59.04±1.46	69.29±2.13	60.00±3.79
S. D. .....yrs.	18.84±1.21	15.97±0.82	14.88±1.20	22.87±2.14
C. V. ..percent	35.80±2.58	26.78±1.47	22.50±1.90	41.58±4.51
Range .....yrs.	21-85	21-90	30-91	17-85

is prejudicial to longevity, but mostly the excess adiposity with which they are dealing is nutritional in origin. On the other hand there is some evidence that the true constitutional pyknic habitus of body is not only not harmful but may in fact be favorable to longevity.

It may be possible to throw a little light on the question so far as concerns the present material by asking the following question: How does the actually realized mean duration of life in the several bodily habitus groups in the present material compare with that to be expected from general population life tables for comparable groups? The data

TABLE 3

Achieved and Expected Mean Duration of Life

GROUP	LOWEST BIRTHDAY BEYOND WHICH ALL INDIVIDUALS IN GROUP LIVED (*years*)	MEAN AGE AT DEATH EXPECTED FROM LIFE TABLES $\mathring{e}_0 + x$ (*years*)	MEAN AGE AT DEATH ACTUALLY OBSERVED (*years*)	EXCESS (+) OR DEFECT (—) OF OBSERVED MEAN AGE AT DEATH AS COMPARED WITH EXPECTED (*years*)	PERCENTAGE GAIN OR LOSS IN LIFE DURATION RELATIVE TO EXPECTANCY (*percent*)
Negro female pyknics	30	58.31	66.14	+7.83	+13.4
Negro male intermediates	24	51.61	57.33	+5.72	+11.1
Negro female intermediates	21	54.56	59.65	+5.09	+ 9.3
Negro male dysplastics	15	48.10	51.47	+3.37	+ 7.0
Negro female dysplastics	17	52.77	55.00	+2.23	+ 4.2
Negro male pyknics	31	56.00	58.23	+2.23	+ 4.0
White female intermediates	33	67.63	68.00	+0.37	+ 0.5
White male dysplastics	12	61.56	60.71	—0.85	— 1.4
White female pyknics	32	67.40	65.67	—1.73	— 2.6
White female asthenics	19	64.71	62.90	—1.81	— 2.8
Negro female asthenics	21	54.56	52.64	—1.92	— 3.5
Negro male asthenics	21	50.21	48.13	—2.08	— 4.1
White female dysplastics	16	64.25	60.79	—3.46	— 5.4
White male pyknics	35	66.08	62.41	—3.67	— 5.6
White male intermediates	20	62.71	58.27	—4.44	— 7.1
White male asthenics	22	63.13	55.11	—8.02	—12.7

necessary to discuss this question are given in Table 3, which has been constructed on the same principles, and by the use of the same life tables, as were used in forming Table 3 of our earlier endocrine paper.[2] The items in the table are arranged in descending order of percentage gain (or loss) in mean life duration as compared with expectancy.

The most striking result shown by Table 3 is that all four asthenic groups in this material failed to achieve as great average duration of life as would be expected from the life table experience of comparable groups of the general population, by amounts ranging from 2.8 to 12.7 percent of expectancy. On the other hand the intermediates, with the sole exception of the white males, equalled or exceeded in their actual mean duration of life the expectancy of comparable general population groups. The pyknics and dysplastics showed different results according to race, the Negroes exceeding, and the whites falling short of their respective life table expectancies. In the present arrangement of the material, just as in our earlier paper,[2] the Negroes in general tend to exhibit a greater excess of achieved mean life duration over the life table expectations of life for comparable groups than do the whites. Possible reasons for this result are discussed in the earlier paper and need not be repeated here.

BODY LENGTH

As was pointed out and discussed in our earlier paper[2] body length measured on the cadaver is not the same thing as stature measured on the living body. This point should be kept in mind throughout the discussion that follows, wherever body length is involved.

The biometric constants for body length by bodily habitus groups are given in Table 4.

From Table 4 the following points may be noted:

1. In the whites, both male and female, and in the Negro females, the asthenics exhibit the highest mean body length, as would in general be expected from the consideration that the asthenic type represents a preponderantly longitudinal habit of growth. In each of these three cases the difference between the asthenic mean body length and the mean for the bodily habitus group showing the shortest body length is statistically significant, amounting in each case to well over four times its probable error. In the Negro males the intermediate bodily habitus group shows the highest mean body length, but this mean is

TABLE 4

Biometric Constants for Body Length

	ASTHENICS	INTERMEDIATES	PYKNICS	DYSPLASTICS
White Males N	180	192	84	84
Mean .....cms.	171.97±0.33	170.83±0.33	169.58±0.44	170.30±0.68
Median ....cms.	171.60±0.41	169.71±0.42	169.62±0.55	171.67±0.86
S. D. .....cms.	6.51±0.23	6.87±0.24	5.94±0.31	9.30±0.48
C. V. ..percent	3.78±0.13	4.02±0.14	3.50±0.18	5.46±0.29
Range ....cms.	155-194	154-190	158-185	122-193
White Females N	80	58	45	38
Mean .....cms.	159.19±0.47	156.81±0.70	158.61±0.72	153.03±0.86
Median ....cms.	158.37±0.59	157.50±0.87	157.50±0.90	153.00±1.08
S. D. .....cms.	6.27±0.33	7.85±0.49	7.14±0.51	7.85±0.61
C. V. ..percent	3.94±0.21	5.00±0.31	4.50±0.32	5.13±0.40
Range ....cms.	140-176	137-172	146-183	127-168
Negro Males N	98	129	29	34
Mean .....cms.	168.88±0.46	170.95±0.42	167.50±0.85	167.06±1.22
Median ...cms.	169.00±0.58	170.93±0.53	168.93±1.07	167.50±1.53
S. D. .....cms.	6.77±0.33	7.12±0.30	6.82±0.60	10.53±0.86
C. V. ..percent	4.01±0.19	4.17±0.18	4.07±0.36	6.30±0.52
Range ....cms.	151-185	156-190	153-178	146-184
Negro Females N	55	86	35	24
Mean .....cms.	159.86±0.59	158.66±0.50	157.21±0.73	154.17±1.19
Median ....cms.	159.83±0.74	158.33±0.63	156.39±0.92	156.00±1.49
S. D. .....cms.	6.53±0.42	6.89±0.35	6.43±0.52	8.62±0.84
C. V. ..percent	4.08±0.26	4.34±0.22	4.09±0.33	5.59±0.55
Range ....cms.	144-172	145-177	145-171	122-165

not significantly greater than the shortest mean body length in the Negro males, which is found in the dysplastic group.

2. The lowest mean body length is found in the pyknic group, where on general grounds it might reasonably be expected, only in the white males. In the other three race-sex divisions of the material it falls in the dysplastic group.

3. All of the body length distributions are substantially symmetrical, the difference between mean and mode being statistically significant in none of the cases.

4. The Negro males exhibit shorter mean body lengths than the white males in all bodily habitus groups except the intermediate, but generally the differences are not statistically significant. The Negro females, on the other hand, have insignificantly greater mean body lengths than the white females, except for the pyknics where the Negroes are shorter.

5. There are no striking or significant differences in absolute (standard deviation) or relative (C. of V.) variability in body length between the several bodily habitus groups, except for the fact that the dysplastics are uniformly much more variable in respect of this character than any of the other groups. Quite evidently the dysplastic group, as here constituted, is not a homogeneous one.

It is of some interest to compare the present data as to body length with Plattner's[5] for Swiss schizophrenes, and Pearl and Ciocco's[6] for American cardiac and non-cardiac hospital patients. This is done for the "pure" bodily habitus types (white males only) in Table 5. In this table the series are arranged, under each of the four constants, in *descending* order of values for the *asthenic* group.

Table 5 brings out some interesting peculiarities of the four series compared, partly resting on true biological differences between them, but probably also resting partly on differences of procedure and judgment in classifying the material according to somatologic types. Thus while among the *asthenics* the Pearl-Ciocco non-cardiac series is the tallest, among the intermediates and pyknics the present data give the largest mean. Plattner's schizophrenes show consistently the lowest

[5] Plattner, W. Körperbauuntersuchungen bei Schizophrenen. *Zürich* (Füssli) 1932. Pp. 347. [*Arch. d. Julius Klaus-Stiftung, Ergänzungs-Bd.* zu Bd. 7, 1932].

[6] Pearl, R., and A. Ciocco. Studies on constitution. II. Somatological differences associated with diseases of the heart in white males. HUMAN BIOLOGY, Vol. 6, pp. 650-713, 1934.

TABLE 5

Comparison Table relative to Stature (or Body Length) in Bodily Habitus Groups. White Males

CONSTANTS AND SERIES	ASTHENICS	INTERMEDIATES	PYKNICS
Means (cm.)			
Pearl and Ciocco. Non-cardiacs ..	180.35±1.72	170.13± .92	162.50±1.74
Pearl and Ciocco. Cardiacs	176.88±1.72	168.39± .56	168.09± .96
Present data	**171.97± .33**	**170.83± .33**	**169.58± .44**
Plattner. Swiss schizophrenes ...	165.5 ± .86	168.0 ±1.10	162.4 ±1.05
Unweighted averages	173.7	169.3	165.6
Standard Deviations (cm.)			
Pearl and Ciocco. Cardiacs	7.63±1.22	6.54± .40	5.84± .68
Plattner. Swiss schizophrenes...	7.02± .61	6.51± .78	5.15± .74
Present data	**6.51± .23**	**6.87± .24**	**5.94± .31**
Pearl and Ciocco. Non-cardiacs ..	6.24±1.21	8.37± .65	6.33±1.23
Unweighted averages	6.85	7.00	5.82
Coefficients of Variation (percent)			
Pearl and Ciocco. Cardiacs	4.31± .73	3.88± .24	3.47± .40
Plattner. Swiss schizophrenes....	4.24± .37	3.88± .47	3.17± .46
Present data	**3.78± .13**	**4.02± .14**	**3.50± .18**
Pearl and Ciocco. Non-cardiacs ..	3.46± .67	4.92± .38	3.90± .76
Unweighted averages	3.95	4.18	3.51
Ranges (cm.)			
Present data	**39.0**	**36.0**	**27.0**
Plattner. Swiss schizophrenes	25.3	23.3	15.9
Pearl and Ciocco. Cardiacs	23.9	33.9	19.1
Pearl and Ciocco. Non-cardiacs....	13.8	33.7	12.3
Unweighted averages	25.5	31.7	18.6

means in all habitus groups, though many of the differences are not significant. This undoubtedly reflects a definite racial difference to the other three groups compared.

The general tendency is for mean stature (or body length) to decrease as we pass from asthenics, through intermediates, to pyknics. This tendency is clearly shown in the unweighted averages of the four series of means. The only exception to the rule is Plattner's data, where the intermediates have an insignificantly greater stature than the asthenics.

The variability in stature (or body length), whether measured by standard deviation, coefficient of variation, or range, tends to be lower in pyknics than in asthenics. In this respect morphology in a sense parallels the psychological characteristics of the two groups; asthenics, on the whole, tending to be less stable and placid mentally and temperamentally than pyknics.

BODY WEIGHT

The biometric constants for body weight (including body weight ratio)[7] by bodily habitus types are given in Table 6.

As would be expected from the general characteristics of the several bodily habitus types the mean body weight increases as we pass from asthenics to intermediates to pyknics, with the dysplastics falling generally between the asthenics and the intermediates in mean body weight.

A comparison of means and medians indicates that the distributions are substantially symmetrical in the "pure" somatological types. The dysplastic distributions exhibit a somewhat greater tendency to skewness.

There is no regular or striking differentiation between the "pure" types in respect of variation in body weight. But the dysplastics are plainly more variable in this character than the pure types. This tendency reflects again the heterogeneity of the dysplastic group, to which attention has already been called.

Tables 7 and 8 are comparative tables similar to Table 5, but for body weight and body weight ratio respectively.

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[7] This index of body build, which gives the mean weight in kg. of the average 10 cm. thick horizontal section of the body, has been discussed at length by Pearl and Ciocco[8], and Pearl, Gooch, and Freeman.[9]

TABLE 6

Biometric Constants for Body Weight

	ASTHENICS	INTERMEDIATES	PYKNICS	DYSPLASTICS
White Males N	180	191	81	79
Mean .....(kg.)	43.83±0.39	55.63±0.52	70.56±0.97	52.97±1.10
Median .....(kg.)	43.14±0.49	54.45±0.66	69.42±1.22	51.32±1.38
S. D. .....(kg.)	7.70±0.27	10.71±0.37	12.96±0.69	14.53±0.78
C. V. .....percent	17.57±0.64	19.26±0.69	18.37±1.01	27.43±1.58
Range .....(kg.)	28-70	30-96	44-115	18-95
Body weight ratio	2.55	3.26	4.16	3.11
White Females N	81	59	44	36
Mean .....(kg.)	33.92±0.52	43.01±0.83	65.00±1.56	41.39±1.82
Median .....(kg.)	33.56±0.66	42.25±1.04	63.00±1.96	37.50±2.28
S. D. .....(kg.)	6.99±0.37	9.46±0.59	15.37±1.11	16.19±1.29
C. V. .....percent	20.62±1.14	22.01±1.43	23.65±1.79	39.11±3.55
Range .....(kg.)	20-58	24-64	28-102	16-100
Body weight ratio	2.13	2.74	4.10	2.71
Negro Males N	98	124	28	31
Mean .....(kg.)	40.92±0.41	54.84±0.61	72.86±1.46	49.84±1.79
Median .....(kg.)	40.78±0.51	54.58±0.77	71.00±1.83	46.82±2.24
S. D. .....(kg.)	6.00±0.29	10.09±0.43	11.45±1.03	14.78±1.27
C. V. .....percent	14.67±0.72	18.40±0.81	15.72±1.45	29.66±2.76
Range .....(kg.)	21-56	34-77	54-105	26-85
Body weight ratio	2.42	3.21	4.35	2.98
Negro Females N	55	84	35	25
Mean .....(kg.)	35.55±0.61	46.67±0.73	63.00±1.36	42.60±1.59
Median .....(kg.)	35.30±0.77	46.43±0.92	63.21±1.70	42.27±1.99
S. D. .....(kg.)	6.72±0.43	9.98±0.52	11.90±0.96	11.76±1.12
C. V. .....percent	18.91±1.26	21.39±1.16	18.90±1.58	27.60±2.83
Range .....(kg.)	23-52	29-67	41-86	16-74
Body weight ratio	2.22	2.94	4.01	2.76

TABLE 7

Comparison Table relative to Body Weight in Bodily Habitus Groups
White Males

CONSTANTS AND SERIES	ASTHENICS	INTERMEDIATES	PYKNICS
Means (kg.)			
Pearl and Ciocco. Cardiacs	59.29±2.42	66.83± .93	90.29±3.13
Pearl and Ciocco. Non-cardiacs ..	58.33±4.15	64.19± .99	74.83±2.08
Plattner's Swiss schizophrenes ..	54.4 ± .77	68.1 ±1.38	79.2 ±3.18
Present data	**43.83± .39**	**55.63± .52**	**70.56± .97**
Unweighted averages	53.96	63.69	78.72
Standard deviations (kg.)			
Pearl and Ciocco. Non-cardiacs ..	15.08±2.94	8.96± .70	7.56±1.47
Pearl and Ciocco. Cardiacs	9.49±1.71	10.65± .66	19.13±2.21
Present data	**7.70± .27**	**10.71± .37**	**12.96± .69**
Plattner's Swiss schizophrenes ..	6.27± .55	8.15± .97	15.66±2.25
Unweighted averages	9.64	9.62	13.83
Coefficients of variation (percent)			
Pearl and Ciocco. Non-cardiacs ..	25.85±5.36	13.96±1.12	10.10±1.99
Present data	**17.57± .64**	**19.26± .69**	**18.37±1.01**
Pearl and Ciocco. Cardiacs	16.01±2.96	15.94±1.01	21.19±2.56
Plattner's Swiss schizophrenes ..	11.53±1.00	11.97±1.42	19.77±2.85
Unweighted averages	17.74	15.28	17.36
Range (kg.)			
Present data	**42**	**66**	**71**
Pearl and Ciocco. Non-cardiacs ..	41.2	50.0	19.1
Pearl and Ciocco. Cardiacs	31.1	53.6	68.0
Plattner's Swiss schizophrenes ..	24.5	26.3	47.0
Unweighted averages	34.7	49.0	51.3

TABLE 8

Comparison Table relative to Body Weight Ratio in Bodily Habitus Groups White Males

CONSTANTS AND SERIES	ASTHENICS	INTERMEDIATES	PYKNICS
Means (kg. per 10 cm. of stature)			
Pearl and Ciocco. Cardiacs	3.35	3.97	5.37
Plattner's Swiss schizophrenes ..	3.29	4.05	4.88
Pearl and Ciocco. Non-cardiacs ..	3.23	3.77	4.60
Present data	**2.55**	**3.26**	**4.16**
Unweighted average	3.11	3.76	4.75

From Table 7 it is evident that generally mean body weight rises as we pass from asthenics to intermediates and from intermediates to pyknics. This is true in each of the four series compared and therefore necessarily so for the averages. Pearl and Ciocco's cardiacs are the heaviest in all habitus types except the intermediate, and the present material the lightest in all habitus types. This latter relation is in part at least a reflection of the fact that in the present material we are dealing with dead bodies rather than living as in the other series.

The variability in body weight, when measured in absolute units, tends to be markedly greater in the pyknics than in either of the other two types, as would be expected from the greater absolute body weights of the pyknics. But when measured by the coefficient of variation the relative variability in body weight is not strikingly different in the three habitus types.

The mean body weight ratios of Table 8 are strikingly smooth and regular in their trends, increasing in all the series from roughly ½ to ¾ of a kg. per 10 cm. of stature as we pass from asthenics to intermediates, and from roughly 8/10 to well over 1 kg. per 10 cm. of stature as we pass from intermediates to pyknics. With the exception only of the intermediates Pearl and Ciocco's cardiac series has the highest body weight ratio of all the series compared, in all habitus types. The present material shows the lowest body weight ratio in all

habitus types, again at least probably partly due to the fact that the data were taken on cadavers.

The present material yields a somewhat unexpected result respecting the *correlation* between body length and body weight in the three body habitus types. The coefficients are set forth in Table 9, all the correlations being linear well within the errors of sampling. The purpose of computing these correlations was primarily to see whether the actual observations would accord with the trend to be expected on *a priori* grounds of the highest stature-body weight correlations in the asthenics, the lowest in the pyknics, and values between these extremes in the intermediates.

TABLE 9

Coefficients of Correlation between Body Length and Body Weight

GROUP	ASTHENICS		INTERMEDIATES		PYKNICS	
	N	*r*	*N*	*r*	*N*	*r*
White males ...	178	+.399±.051	191	+.540±.049	81	+.524±.075
White females ..	80	+.370±.075	58	+.602±.089	44	+.397±.102
Negro males	98	+.374±.068	123	+.521±.061	27	+.548±.130
Negro females ..	55	+.188±.091	84	+.502±.074	35	+.308±.114
Unweighted averages		+.333	...	+.541	..	+.444

The actually observed correlation results of Table 9, though generally quite smooth and regular, plainly do not accord in their trends with the expectation based upon the linear and lateral growth relationships in the several habitus types. So far from the stature-body weight correlations being highest in the asthenics they are, on the whole, the lowest. While most of the differences between individual pairs of coefficients in the table are not statistically significant, the general trend of the results is plain. We are unable to explain the somewhat paradoxical result. Possibly it is again connected in some obscure manner with the fact that we are dealing with autopsy material.

SOMATOLOGICAL HABITUS TYPE DISTRIBUTIONS

In Table 10 are presented percentage frequencies of habitus types from various series of observations for comparison with the present material. The mode of presentation is uniform for all series, the percentages having been computed by us from the original data according to the following plan: First the percentage of persons recorded as dysplastic is calculated on the basis of the total number of observations and set down in the last column; then the percentages of asthenics, intermediates, and pyknics are calculated on the basis of the total number of persons recorded as falling into "pure" types. In other words the percentages of asthenics, intermediates, and pyknics as set forth in Table 10 *add to 100.* The percentages of dysplastics have no relation to the percentages preceding them in the first three columns of figures, but represent the proportion of dysplastics in the total series of "pure" types + dysplastics. This procedure is in accord with the writer's general concept that dysplastics form a differentiated category always to be dealt with *separated* from "pure" types.

Table 10 could, of course, be greatly lengthened by the inclusion of other series from the literature, but the number included is deemed sufficient to bring out the main points that we wish to discuss.

From Table 10 it is at once evident that exact and rigorous criteria for somatic habitus classification do not, in fact, exist at the present time. Different observers, operating through the medium of purely qualitative judgments, reach widely different results. In the 19 series included in Table 10 the percentage of asthenics ranges from 6.2 to 71.0; that of intermediates from 4.6 to 76.0; that of pyknics from 1.8 to 89.2! It is obviously impossible to suppose that any such extensive variation can be wholly due to real objective differences between the groups subjected to somatological classification. Common experience of the extent of the normal morphological variability of man precludes any such view. There evidently is a large element of personal difference between the classifiers in their conception of what the categories "asthenic," "intermediate," and "pyknic" really mean. On any rational view of the case it would be expected that the distribution of frequency of individuals between the categories of asthenic, intermediate and pyknic would in some degree approximate to a normal distribution, with definitely higher frequency of the middle class (intermediates) than of either of the extreme classes (asthenics or pyknics), especially when it is remembered that asthenics and pyknics

TABLE 10

Percentage Distributions of "Pure" Habitus Types, and Proportion of Dysplastics to Total Individuals Observed

GROUP	*N*	PERCENTAGE DISTRIBUTION OF THE THREE "PURE" TYPES			PERCENT OF DYSPLASTICS IN TOTAL	AUTHORITY
		Asthenic	Intermediate	Pyknic		
German (Schwabian) schizophrenes, males	175	71.0	27.2	1.8	19.4	Kretschmer,[14], p. 35
Japanese official class, males	256	70.4[9]	26.5[9]	3.1[10]	...[11]	Bean,[13] Table 3, p. 367
Zürich schizophrenes, males	100	46.7	33.3	20.0	10.0	Plattner,[12] p. 37. Own data
Present data. White females	**224**	**43.5**	**32.3**	**24.2**	**16.9**	This paper
Present data. White males	**549**	**39.6**	**42.2**	**18.2**	**15.3**	This paper
Present data. Negro males	**297**	**37.6**	**50.6**	**11.8**	**11.5**	This paper
American non-cardiacs, males. Limb habitus	50	34	62	4	...[15]	Pearl and Ciocco, [16] pp. 702 and 703
American cardiacs, males Limb habitus	87	33	62	5	...[17]	Pearl and Ciocco, [16] pp. 702 and 703
Present data. Negro females	**202**	**31.3**	**48.9**	**19.9**	**12.9**	This paper
Filipino adult females	89	28.1[8]	52.8[9]	19.1[10]	...[11]	Computed from data of Bean's,[13] Table 5, p. 369
Japanese, both official and laborer class, females	442	26.9[8]	45.5[9]	27.6[10]	...[11]	Bean,[13] Table 3, p. 367

American psychiatric patients, males	65	24.1	31.0	44.8	18.5	Wertheimer and Hesketh,[15] pp. 26 and 29
Filipino adult males	350	21.1[8]	72.9[9]	6.0[10]	...[11]	Computed from data of Bean's,[13] Table 5, p. 369
American females. Trunk habitus	290	19.3	56.2	24.5	19.7	Pearl,[3] pp. 73 and 79
American females. Limb habitus	290	14.8	62.4	22.8		Pearl,[3] pp. 73 and 79
Japanese laborers, males	3812	13.6[8]	58.3[9]	28.1[10]	...[11]	Bean,[13] Table 3, p. 367
American non-cardiacs, males. Trunk habitus	50	12	76	12	...[18]	Pearl and Ciocco, [16] pp. 702 and 703
American cardiacs, males Trunk habitus	87	9	71	20	...[17]	Pearl and Ciocco, [16] pp. 702 and 703
German (Schwabian) cycloids, males	85	6.2	4.6	89.2	0	Kretschmer,[14] p. 35

[8] "Hypermorph"

[9] "Mesomorph"

[10] "Hypomorph"

[11] Bean does not distinguish a dysplastic group in his morphologic typing.

[13] Bean, R. B. Human types. *Quart. Rev. Biol.*, Vol. 1, pp. 360-392, 1926.

[3] Plattner, W. Körperbauuntersuchungen bei Schizophrenen. *Arch. der Julius Klaus Stiftung*.....Zürich, *Ergänzungsbd.* zu Bd. 7, pp. 1-347, 1932.

[14] Kretschmer, E. Physique and Character. *London* (Kegan Paul, Trench, Trubner and Co.), 1925. Pp. xiv + 266.

[15] Wertheimer, F. I., and Florence E. Hesketh. The Significance of the Physical Constitution in Mental Disease. *Baltimore* (Williams and Wilkins), 1926. Pp. xiv + 76 + 5 pl.

[16] Pearl, R., and A. Ciocco. Studies on constitution. II. Somatological differences associated with diseases of the heart in white males. HUMAN BIOLOGY, Vol. 6, pp. 650-713, 1934.

[17] The percentage of dysplastics in the American male cardiac group is 44.8

[18] The percentage of dysplastics in the American male non-cardiac group is 30.0

are expressions of real biological extremes in growth tendencies,[19] and if it be postulated as it usually is that the sample typed is a reasonably random sample of a reasonably homogeneous population. Such extremely skewed distributions as those of Kretschmer's Schwabian cycloids and schizophrenes suggest to the biometrician that either definite, direct selection relative to somatic habitus played a large rôle in the formation of the sample, or that the working concepts of the habitus type categories were extremely elastic ones.

It is difficult to think of anything that would more clearly demonstrate than Table 10 does the great need for more precise and objective criteria in somatological classification. We feel in this laboratory after long and varied experience that our standard method[3, 4] of typing against a dual scale for trunk and limbs separately, while by no means ideal or perfect, is a small step in the right direction. It is particularly useful in enabling a more precise and logical definition of dysplasticity. In the 11 series of Table 10 in which any attempt was made to distinguish dysplastics the recorded percentages range from 0 to 44.8 percent of the total sample. Here again such a range of variation violates common sense. On our plan of typing the definition of what degree of asymmetry of development exists as between trunk and limbs may be set at any point quantitatively that one desires. Perhaps we have, in our practice, set it at too fine a point—that is so as to mark off for the dysplastic category too small a degree of asymmetrical development —but if this should prove to be the consensus of opinion the definition can be easily altered to make a coarser discrimination. But in any case we have a perfectly clear, logically quantitatively defined conception of what we mean by dysplasticity.

BIOMETRIC CONSTANTS FOR ENDOCRINE ORGAN ABSOLUTE WEIGHTS BY SOMATIC HABITUS TYPES

In Tables 11-14 inclusive are set forth, for permanent record and future reference, the biometric constants for the weights of the several endocrine organs. We do not propose to discuss in detail the data of these tables, for the reasons first that the absolute weights of these organs have been discussed in detail in our earlier paper and second that it appears to us that *relative* endocrine weights are much more significant and important than absolute weights in connection with the somatic habitus problem.

[19] See Pearl's[3] *Constitution and Health* for a discussion of this point.

TABLE 11
Mean Endocrine Organ Weights

TABLE 11

Mean Endocrine Organ Weights

HABITUS, RACE AND SEX GROUPS	RIGHT ADRENAL (*gm.*)	LEFT ADRENAL (*gm.*)	THYROID (*gm.*)	PARA-THYROIDS (*mgm.*)	HYPO-PHYSIS (*mgm.*)	RIGHT GONAD (*gm.*)	LEFT GONAD (*gm.*)	EPI-PHYSIS (*mgm.*)	THYMUS (*gm.*)
Asthenics									
White males ...	6.86±.10 (153)	7.23±.11 (152)	19.63± .41 (155)	134.9± 3.4 (157)	671.4± 8.6 (159)	13.40±.24 (155)	12.92±.23 (156)	171.8± 4.2 (157)	11.95± .43 (154)
White females ..	6.23±.14 (71)	6.37±.13 (71)	15.53± .52 (66)	142.9± 4.6 (70)	730.8±10.2 (73)	1.94±.13 (61)	1.87±.13 (59)	180.1± 6.3 (69)	8.91± .49 (71)
Negro males ...	6.42±.13 (85)	6.95±.15 (84)	20.41± .55 (86)	156.4± 5.0 (86)	678.7± 8.8 (87)	11.23±.26 (86)	11.47±.28 (85)	142.6± 5.8 (88)	7.44± .28 (88)
Negro females ..	5.94±.11 (50)	6.48±.14 (50)	19.35± .81 (46)	151.5± 7.1 (51)	802.0±17.0 (50)	2.85±.18 (34)	2.47±.14 (34)	172.9±11.5 (47)	7.50± .42 (49)
Intermediates									
White males ...	7.44±.11 (156)	7.91±.12 (158)	22.53± .54 (145)	147.5± 3.7 (149)	708.1± 8.3 (155)	16.67±.29 (156)	15.60±.28 (155)	168.7± 5.5 (142)	18.40± .70 (153)
White females ..	6.63±.14 (54)	6.85±.18 (55)	16.20± .62 (46)	152.3± 6.5 (55)	807.7±15.8 (52)	2.18±.15 (44)	1.96±.11 (41)	177.8± 7.1 (53)	15.46±1.09 (54)
Negro males ...	6.82±.13 (121)	7.56±.14 (121)	22.89± .59 (114)	177.1± 5.4 (120)	763.8± 9.8 (116)	13.52±.25 (119)	13.40±.25 (120)	157.9± 5.0 (111)	12.58± .50 (119)
Negro females ..	6.10±.12 (77)	6.87±.16 (76)	20.29± .55 (68)	161.8± 5.8 (76)	847.3±14.7 (75)	2.57±.15 (60)	2.35±.13 (53)	165.0± 6.6 (75)	11.97± .63 (75)
Pyknics									
White males ...	8.47±.19 (74)	8.34±.19 (73)	25.74± .67 (71)	180.4± 6.8 (74)	704.7± 9.5 (75)	18.26±.49 (72)	17.22±.48 (71)	202.7± 7.3 (74)	25.81±1.42 (74)
White females ..	8.01±.22 (43)	8.41±.23 (43)	20.13±1.07 (40)	156.7± 8.1 (41)	802.4±16.7 (42)	2.18±.14 (37)	1.93±.11 (35)	207.6± 8.5 (43)	27.50±1.57 (42)
Negro males ...	7.50±.37 (23)	8.50±.49 (22)	28.93±1.23 (21)	185.4±12.3 (24)	758.7±21.1 (23)	15.86±.81 (21)	16.39±.86 (23)	152.3±10.1 (22)	25.42±2.24 (24)
Negro females ..	6.30±.23 (35)	6.61±.23 (35)	26.02±1.38 (27)	208.3±12.4 (33)	891.2±19.5 (34)	2.42±.28 (25)	2.22±.26 (25)	146.4±10.0 (35)	20.63±1.38 (32)
Dysplastics									
White males ...	7.48±.16 (80)	7.99±.19 (79)	22.11± .61 (77)	158.5± 5.6 (82)	706.0±12.0 (75)	14.19±.38 (80)	12.81±.40 (80)	157.5± 5.6 (80)	20.50±1.13 (80)
White females ..	5.64±.18 (35)	5.50±.22 (34)	16.47± .91 (29)	128.0± 7.1 (33)	705.9±18.4 (34)	2.37±.22 (30)	2.10±.19 (30)	173.5±11.3 (34)	13.79±1.01 (35)
Negro males ...	6.89±.27 (33)	7.62±.28 (33)	22.66± .96 (32)	147.7±11.3 (33)	737.5±21.7 (32)	12.13±.66 (32)	12.13±.73 (32)	157.3±12.1 (31)	14.69±1.35 (32)
Negro females ..	5.82±.21 (22)	6.18±.26 (22)	19.72±1.30 (18)	172.7± 9.8 (22)	686.4±30.5 (22)	2.25±.20 (16)	2.31±.22 (16)	116.3± 9.7 (23)	11.79±1.10 (21)

TABLE 12

Median Endocrine Organ Weights

HABITUS, RACE AND SEX GROUPS	RIGHT ADRENAL (gm.)	LEFT ADRENAL (gm.)	THYROID (gm.)	PARA-THYROIDS (mgm.)	HYPO-PHYSIS (mgm.)	RIGHT GONAD (gm.)	LEFT GONAD (gm.)	EPI-PHYSIS (mgm.)	THYMUS (gm.)
Asthenics									
White males ...	6.62±.12	6.90±.14	19.21± .51	125.0± 4.2	655.7±10.8	13.21± .30	12.79± .29	147.9± 5.3	10.19± .54
White females ..	6.20±.17	6.42±.16	15.24± .65	133.9± 5.8	735.7±12.8	1.56± .17	1.50± .17	157.8± 7.9	7.98± .61
Negro males ...	6.27±.17	6.67±.18	19.23± .69	138.6± 6.3	669.8±11.0	11.12± .33	11.29± .35	125.0± 7.2	7.22± .36
Negro females ..	5.75±.14	6.32±.18	17.69±1.01	139.1± 9.0	833.3±21.3	2.50± .22	2.30± .18	135.5±14.4	7.07± .53
Intermediates									
White males ...	7.18±.14	7.80±.16	20.42± .67	134.9± 4.6	734.9±10.4	16.40± .36	15.50± .35	142.0± 6.8	15.92± .88
White females ..	6.56±.18	6.50±.22	15.00± .77	132.3± 8.1	781.3±19.8	1.88± .18	1.70± .14	167.5± 8.9	12.00±1.37
Negro males ...	6.52±.16	7.20±.18	20.95± .74	157.5± 6.8	657.1±12.3	13.12± .31	12.82± .32	137.5± 6.3	11.44± .62
Negro females ..	5.89±.15	6.48±.20	19.04± .69	140.6± 7.3	847.2±18.5	2.00± .19	1.84± .17	144.8± 8.3	11.02± .79
Pyknics									
White males ...	8.29±.23	7.96±.24	26.17± .84	161.1± 8.5	757.7±11.9	18.26± .61	17.33± .61	180.0± 9.1	23.68±1.78
White females ..	7.81±.28	8.35±.29	18.13±1.34	141.7±10.2	800.0±21.0	1.85± .18	1.70± .14	205.4±10.7	25.00±1.97
Negro males ...	6.75±.46	7.80±.61	28.13±1.54	166.7±15.4	762.5±26.5	15.75±1.01	15.63±1.08	133.3±12.7	21.67±2.81
Negro females ..	5.85±.29	6.36±.28	23.21±1.73	177.5±15.6	860.0±24.4	1.85± .35	1.65± .32	129.6±12.5	18.75±1.73
Dysplastics									
White males ...	7.36±.20	7.82±.19	21.41± .76	146.0± 7.0	702.6±15.0	12.97± .47	12.58± .50	138.9± 7.1	16.97±1.42
White females ..	5.79±.23	5.00±.27	16.07±1.14	115.9± 8.9	720.0±23.1	1.78± .27	1.67± .24	143.3±14.1	12.19±1.27
Negro males ...	6.36±.34	7.44±.35	20.71±1.20	132.5±14.2	744.4±27.1	12.00± .83	11.11± .91	132.7±15.1	11.43±1.69
Negro females ..	5.50±.26	5.57±.32	18.75±1.63	175.0±12.3	671.4±38.3	2.17± .25	2.00± .27	105.0±12.1	9.69±1.37

TABLE 13

Standard Deviations of Endocrine Organ Weights

HABITUS, RACE AND SEX GROUPS	RIGHT ADRENAL (gm.)	LEFT ADRENAL (gm.)	THYROID (gm.)	PARA-THYROIDS (mgm.)	HYPO-PHYSIS (mgm.)	RIGHT GONAD (gm.)	LEFT GONAD (gm.)	EPI-PHYSIS (mgm.)	THYMUS (gm.)
Asthenics									
White males	1.83±.07	2.09±.08	7.54±.29	62.4±2.4	161.5± 6.1	4.45±.17	4.27±.16	78.3±4.0	7.92± .30
White females ..	1.74±.10	1.62±.09	6.27±.37	57.4±3.3	128.9± 7.2	1.53±.09	1.52±.09	77.6±4.5	6.12± .35
Negro males	1.82±.09	2.00±.10	7.57±.39	69.3±3.6	121.2± 6.2	3.63±.19	3.77±.19	80.1±4.1	3.95± .20
Negro females ...	1.13±.08	1.50±.10	8.10±.57	75.6±5.1	178.0±12.0	1.55±.13	1.25±.10	116.7±8.1	4.40± .40
Intermediates									
White males ...	2.10±.08	2.32±.09	9.59±.38	66.7±2.6	152.8± 5.9	5.34±.20	5.21±.30	96.4±3.9	12.89± .50
White females ...	1.54±.10	1.94±.12	6.21±.44	71.2±4.6	169.1±11.2	1.44±.10	1.06±.08	76.7±5.0	11.92± .77
Negro males	2.11±.09	2.36±.10	9.30±.42	87.9±3.8	157.0± 7.0	4.03±.18	4.09±.18	78.7±3.6	8.02± .35
Negro females ...	1.51±.08	2.02±.11	6.77±.39	75.4±4.1	189.0±10.4	1.72±.11	1.45±.09	85.2±4.7	8.07± .44
Pyknics									
White males	2.37±.13	2.39±.13	8.35±.47	86.8±4.8	121.4± 6.7	6.10±.34	6.04±.34	92.7±5.1	18.14±1.01
White females ...	2.18±.16	2.24±.16	10.00±.75	77.1±5.7	160.7±11.8	1.30±.10	0.96±.08	82.8±6.0	15.12±1.11
Negro males	2.62±.26	3.41±.35	8.33±.87	89.0±8.7	150.1±14.9	5.47±.57	6.11±.61	70.3±7.2	16.26±1.58
Negro females ...	2.00±.16	1.98±.16	10.61±.97	105.7±8.8	168.2±13.8	2.06±.20	1.91±.18	87.3±7.0	11.58± .98
Dysplastics									
White males	2.07±.11	2.56±.14	7.89±.43	75.3±4.0	153.4± 8.5	4.98±.27	5.32±.28	74.6±4.0	14.99± .80
White females ..	1.59±.13	1.88±.15	7.24±.64	60.2±6.0	159.4±13.0	1.77±.15	1.54±.13	97.4±8.0	8.89± .72
Negro males	2.28±.19	2.41±.20	8.05±.68	96.2±9.0	181.6±15.3	5.52±.47	6.12±.52	99.6±8.6	11.31± .95
Negro females ...	1.43±.15	1.79±.18	8.20±.92	68.2±6.9	212.2±21.6	1.20±.14	1.29±.15	68.6±6.8	7.45± .77

Table 11 gives the means; Table 12 the medians; Table 13 the standard deviations; and Table 14 the coefficients of variation and ranges. In these tables, as was the case in our previous study,[2] definitely pathological organs have been excluded. In Table 11 the figures in brackets in each cell denote the number of individuals in the distribution from which the constant was computed. These same bracketed figures apply to Tables 12, 13 and 14, and are therefore not repeated. In Table 14 the figures in brackets denote the minimum and maximum observations, that is the range.

As would be expected there is evident a tendency for the mean weights of the endocrine organs to increase as we pass from asthenics to intermediates and to pyknics. The same trend is shown in the table of median endocrine weights. As the body weight increases, on the average, from habitus group to group the mean weight of all the endocrine organs tends also to increase.

RELATIVE ENDOCRINE ORGAN WEIGHTS

The real and significant problem of the present investigation is concerned with the relative endocrine gland supply, quantitatively considered, of the three bodily habitus types. How does the quantitative endocrine organ pattern of the asthenics differ from that of the pyknics, if at all; and how do the patterns of each of the extreme types differ from that of the intermediates? Or, put in another way, *do the pyknics, on the average, carry a greater or smaller dosage of endocrine organ tissue than do the asthenics, per kilogram of total body weight in each case?* The answer to these questions is needed not only for the endocrine system as a whole, but also for each of the endocrine organs separately.

To this problem the present section of this paper is devoted. Table 15 gives the mean number of milligrams per kilogram of total body weight for each of the seven endocrine organs separately, and for the sum of them altogether. In the case of the paired organs (adrenals and gonads) the weights of right and left organ have been added together for the computations of Table 15 (and Table 16).

Table 16 gives the mean number of milligrams per kilogram of *relative* body weight (i. e. kilograms of body weight per 10 cm. of body length) for each endocrine organ separately and for the sum of all of them together.

TABLE 14

Coefficients of Variation and Ranges of Endocrine Organ Weights

HABITUS, RACE AND SEX GROUPS	RIGHT ADRENAL	LEFT ADRENAL	THYROID	PARA-THYROIDS	HYPO-PHYSIS	RIGHT GONAD	LEFT GONAD	EPI-

TABLE 14

Coefficients of Variation and Ranges of Endocrine Organ Weights

HABITUS, RACE AND SEX GROUPS	RIGHT ADRENAL (*percent and gm.*)	LEFT ADRENAL (*percent and gm.*)	THYROID (*percent and gm.*)	PARA-THYROIDS (*percent and mgm.*)	HYPO-PHYSIS (*percent and mgm.*)	RIGHT GONAD (*percent and gm.*)	LEFT GONAD (*percent and gm.*)	EPI-PHYSIS (*percent and mgm.*)	THYMUS (*percent and gm.*)
Asthenics									
White males ..	26.7±1.1	28.9±1.2	38.4 ±1.7	46.3±2.1	24.1±1.0	33.2±1.4	33.1±1.4	45.6±2.1	66.3±3.5
	(2.6-11.9)	(3.1-13.3)	(7.2-52.0)	(30-350)	(300-1300)	(3.7-24.3)	(3.6-23.3)	(40-400)	(0.8-31.0)
White females..	27.9±1.7	25.4±1.5	40.4 ±2.7	40.1±2.6	17.6±1.0	78.8±7.2	81.0±7.7	43.1±2.9	68.7±5.4
	(1.7-10.5)	(2.8-11.7)	(5.4-40.0)	(20-300)	(400-950)	(0.3-6.2)	(0.4-7.6)	(50-350)	(0.7-32.0)
Negro males ..	28.4±1.6	28.8±1.6	37.08±2.15	44.3±2.3	17.9± .9	32.3±1.8	32.8±1.9	56.2±3.7	53.1±3.4
	(2.2-9.7)	(3.3-11.9)	(8.6-49.2)	(40-450)	(300-1000)	(2.9-26.4)	(3.2-28.2)	(30-500)	(1.6-16.2)
Negro females..	19.1±1.3	23.2±1.7	41.9 ±3.4	49.9±4.1	22.2±1.6	54.4±5.6	50.5±5.1	67.5±6.5	58.7±5.2
	(4.0-8.0)	(4.0-10.0)	(7.0-42.4)	(20-400)	(100-1100)	(0.4-6.2)	(0.4-5.8)	(50-650)	(1.0-18.4)
Intermediates									
White males ..	28.3±1.2	29.3±1.2	42.5 ±2.0	45.2±2.1	21.6± .9	32.0±1.3	33.4±1.42	57.2±2.9	70.1±3.8
	(2.75-13.0)	(2.7-16.0)	(6.5-55.0)	(20-300)	(350-1250)	(5.2-37.9)	(2.6-30.0)	(20-600)	(0.97-70.0)
White females..	23.2±1.6	28.3±2.0	38.3 ±3.1	46.8±3.6	20.9±1.4	66.1±6.5	54.1±5.1	43.2±3.3	77.1±7.4
	(2.4-10.6)	(2.55-11.8)	(6.7-34.4)	(50-300)	(490-1300)	(0.1-6.0)	(0.5-4.9)	(50-500)	(1.7-74.0)
Negro males ..	30.9±1.5	31.2±1.5	40.6 ±2.1	49.6±2.6	20.6±1.0	29.8±1.4	30.5±1.5	49.9±2.8	63.7±3.8
	(3.2-15.0)	(3.0-17.0)	(2.4-54.5)	(20-500)	(350-1200)	(5.6-21.8)	(5.2-24.2)	(40-450)	(1.3-42.0)
Negro females..	24.8±1.4	29.4±1.7	33.4 ±2.1	46.6±3.1	22.3±1.3	67.1±5.7	61.6±5.4	51.7±3.5	67.4±5.1
	(2.5-9.5)	(3.0-12.0)	(7.4-40.0)	(40-400)	(350-1300)	(0.5-8.1)	(0.5-7.5)	(40-400)	(0.98-45.0)
Pyknics									
White males ..	28.0±1.7	28.6±1.7	32.5 ±2.0	48.1±3.2	17.2±1.0	33.4±2.1	35.1±2.2	45.7±3.0	70.3±5.5
	(3.2-13.7)	(4.0-13.5)	(8.7-45.2)	(50-600)	(300-950)	(2.6-30.5)	(2.5-30.3)	(80-500)	(1.8-80.0)
White females..	27.2±2.1	26.7±2.1	49.7 ±4.6	49.2±4.5	20.0±1.5	59.6±6.1	50.0±5.0	39.9±3.3	55.0±5.1
	(3.3-12.8)	(4.0-15.3)	(4.9-47.5)	(30-350)	(450-1100)	(0.5-6.0)	(0.6-5.3)	(60-400)	(2.0-80.0)
Negro males ..	35.0±3.9	40.1±4.7	28.8 ±3.2	48.0±5.6	19.8±2.0	34.5±4.0	37.3±4.2	46.2±5.8	64.0±8.4
	(3.5-15.5)	(3.0-20.3)	(15.5-45.5)	(50-450)	(400-1000)	(6.7-29.0)	(2.9-30.3)	(50-300)	(5.4-73.0)
Negro females..	31.7±2.8	30.0±2.6	40.8 ±4.3	50.7±5.2	18.9±1.6	85.0±12.7	86.0±12.9	59.6±6.3	56.1±6.0
	(4.0-12.7)	(3.0-12.7)	(8.0-50.0)	(70-500)	(600-1220)	(0.7-9.7)	(0.6-8.2)	(40-400)	(1.35-41.0)
Dysplastics									
White males ..	27.7±1.6	32.0±1.9	35.7 ±2.2	47.5±3.0	21.7±1.3	35.1±2.1	41.6±2.6	47 4±3.0	73.1±5.6
	(1.9-12.3)	(1.9-14.4)	(5.0-39.2)	(25-400)	(400-1100)	(1.5-25.0)	(1.1-24.0)	(40-400)	(2.55-80.0)
White females..	23.9±2.0	34.2±3.1	44.0 ±4.6	47.0±4.7	22.6±1.9	74.6±9.4	73.4±9.2	56.1±5.9	64.5±7.0
	(1.5-7.9)	(2.2-11.1)	(4.2-31.0)	(15-250)	(300-900)	(0.9-8.5)	(0.7-7.5)	(40-550)	(2.5-34.0)
Negro males ..	33.1±3.0	31.6±2.9	35.5 ±3.4	65.1±7.4	24.6±2.2	45.5±4.6	50.5±5.2	63.4±7.3	77.0±9.6
	(3.0-12.7)	(3.2-14.1)	(7.8-42.5)	(30-450)	(300-1100)	(1.7-31.0)	(2.9-30.2)	(30-570)	(1.2-45.5)
Negro females..	24.5±2.6	34.6±3.9	41.6 ±5.4	39.5±4.6	30.9±3.4	53.3±8.0	55.6±8.4	59.0±7.6	63.2±8.8
	(4.0-9.0)	(4.0-10.0)	(7.5-40.0)	(50-300)	(100-1000)	(0.5-5.2)	(0.5-5.9)	(10-250)	(1.25-28.0)

Since the means of Tables 15 and 16 were computed from the means of Tables 4, 6, and 11, and not from distributions of individual variation of relative endocrine weights, the estimation of probable errors presented some difficulties.

The procedure adopted was as follows: The standard deviations of the distributions of the relative endocrine figures (indices) were obtained from the formula

$$\frac{m_1}{m_2}\sqrt{v_1^2 + v_2^2 - 2r_{12}v_1v_2} \qquad \text{(i)}$$

This is the well known approximate formula,[20] in which m denotes a mean, $v = \sigma/m$, and r the coefficient of correlation, and, in the present case the subscript 1 denotes an endocrine organ weight and the subscript 2 the total body weight. The expression (i) neglects higher moments, but the probable errors obtained by its use will be of at least the same order of magnitude as those that would be obtained from the actual uncalculated frequency distributions of indices. Since unpublished computations show that body weight is not substantially correlated with endocrine organ weights we have taken r in (i) as zero throughout. The error made by so doing is in the conservative direction since its tendency is to make the values of the resulting probable errors larger. Since it appeared probable that the correlation between right and left adrenals and right and left gonads would be high—this being usually the case for symmetrical paired organs—the v's used for adrenals and gonads were taken as the means of the v's for the right and left organs.

In calculating the probable errors of Table 16 v for the body weight ratio was obtained by the formula

$$\sqrt{v_1^2 + v_2^2 - 2r_{12}v_1v_2}/(1 + v_2^2 - r_{12}v_1v_2) \qquad \text{(ii)}$$

In (ii) r was given the mean values of Table 7 in Pearl, Gooch and Freeman:[2] namely, for White males +.317; White females +.393; Negro males +.350; Negro females +.198.

The probable errors for the total endocrine system were obtained from the probable errors of the separate organs by the formula

$$\epsilon^2 = \epsilon_1^2 + \epsilon_2^2 + \ldots\ldots + 2r_{12}\epsilon_1\epsilon_2 + \ldots\ldots \qquad \text{(iii)}$$

in which the r's are assumed equal to zero.

[20] Cf. Pearl, R. Introduction to Medical Biometry and Statistics. Second Edit. *Philadelphia* (Saunders) 1930, p. 361.

TABLE 15

Mean Number of Milligrams of Endocrine Organ Weights per Kilogram of Absolute Body Weight

GROUP	MILLIGRAMS PER KILOGRAM OF BODY WEIGHT OF							
	Total endocrine system	Adrenals	Thyroid	Parathyroids	Hypophysis	Gonads (testes or ovaries)	Epiphysis	Thymus
Asthenic								
White males	1664±20	321± 5.8	448±10.2	3.08±.082	15.3±.24	600±12.2	3.92±.103	273±10.2
White females	1235±26	371±10.0	458±17.2	4.21±.153	21.5±.46	112± 8.1	5.31±.206	263±15.1
Negro males	1587±23	327± 7.7	499±14.5	3.82±.130	16.6±.28	555±14.5	3.49±.146	182± 7.2
Negro females	1286±31	349± 9.5	544±24.8	4.26±.215	22.6±.63	150± 9.7	4.86±.335	211±12.6
Intermediate								
White males	1610±21	276± 5.2	405±10.6	2.65±.072	12.7±.20	580±11.9	3.03±.103	331±13.1
White females	1171±33	313± 9.7	377±16.6	3.54±.166	18.8±.53	96± 6.5	4.13±.185	359±26.4
Negro males	1419±19	262± 5.8	417±11.8	3.23±.105	13.9±.24	491±10.7	2.88±.098	229± 9.4
Negro females	1099±22	278± 7.4	435±14.1	3.47±.138	18.2±.44	105± 6.3	3.54±.154	256±14.1
Pyknic								
White males	1487±29	238± 6.3	365±10.9	2.56±.103	10.0±.20	503±15.7	2.87±.111	366±20.8
White females	1067±34	253± 9.3	310±18.2	2.41±.139	12.3±.40	63± 4.3	3.19±.152	423±26.3
Negro males	1424±47	220±12.9	397±19.2	2.54±.177	10.4±.37	443±25.6	2.09±.147	349±31.7
Negro females	1039±36	205± 8.5	413±24.1	3.31±.210	14.1±.44	74± 8.7	2.32±.165	327±23.1
Dysplastic								
White males	1625±34	292± 9.0	417±14.4	2.99±.122	13.3±.36	510±18.1	2.97±.123	387±22.8
White females	1132±45	269±15.2	398±29.3	3.09±.222	17.1±.89	108±11.1	4.19±.332	333±28.6
Negro males	1549±53	291±15.0	455±25.1	2.96±.249	14.8±.68	487±32.8	3.16±.268	295±29.0
Negro females	1152±50	282±16.4	463±36.7	4.05±.281	16.1±.96	107±11.0	2.73±.250	277±28.1

TABLE 16

Mean Number of Milligrams of Endocrine Organ Weights per Kilogram of Relative Body Weight

GROUP	MILLIGRAMS PER KG. OF BODY WEIGHT PER 10 CM. OF BODY LENGTH							
	Total endocrine system	Adrenals	Thyroid	Para-thyroids	Hypophysis	Gonads (testes or ovaries)	Epiphysis	Thymus
Asthenic								
White males	28,627±337	5528± 98	7701±175	52.91±1.40	263.4± 4.1	10326±208	67.4±1.8	4688±174
White females	19,664±414	5913±156	7288±271	67.04±2.41	342.9± 7.1	1788±129	84.5±3.2	4181±239
Negro males	26,785±386	5518±129	8423±242	64.55±2.18	280.1± 4.6	9369±243	58.9±2.5	3071±121
Negro females	20,556±493	5585±150	8701±396	68.11±3.43	360.6±10.0	2392±154	77.7±5.4	3372±200
Intermediate								
White males	27,511±361	4714± 87	6920±180	45.30±1.22	217.5± 3.3	9911±202	51.8±1.8	5651±223
White females	18,380±518	4914±149	5906±256	55.51±2.58	294.5± 8.1	1509±101	64.8±2.9	5636±413
Negro males	24,273±328	4483± 98	7135±199	55.20±1.79	238.1± 4.0	8392±181	49.2±1.7	3921±160
Negro females	17,446±352	4409±117	6897±222	55.01±2.17	288.0± 6.9	1672±105	56.1±2.4	4069±224
Pyknic								
White males	25,217±488	4040±106	6186±183	43.36±1.74	169.4± 3.2	8527±263	48.7±1.9	6203±352
White females	16,918±528	4007±144	4912±286	38.24±2.18	195.8± 6.1	1003± 68	50.6±2.4	6711±415
Negro males	23,839±777	3678±213	6651±317	42.63±2.95	174.4± 6.1	7414±424	35.0±2.4	5844±528
Negro females	16,333±558	3222±132	6494±378	51.99±3.30	222.4± 6.8	1158±137	36.5±2.6	5148±363
Dysplastic								
White males	27,686±568	4974±150	7109±242	50.98±2.06	227.0± 6.0	8682±304	50.6±2.1	6592±386
White females	17,331±680	4118±226	6089±441	47.33±3.35	261.0±13.2	1653±169	64.2±5.0	5098±434
Negro males	25,867±866	4864±245	7596±410	49.52±4.12	247.2±11.0	8133±539	52.7±4.4	4925±481
Negro females	17,750±771	4343±250	7137±563	62.52±4.30	248.4±14.7	1650±169	42.1±3.8	4267±432

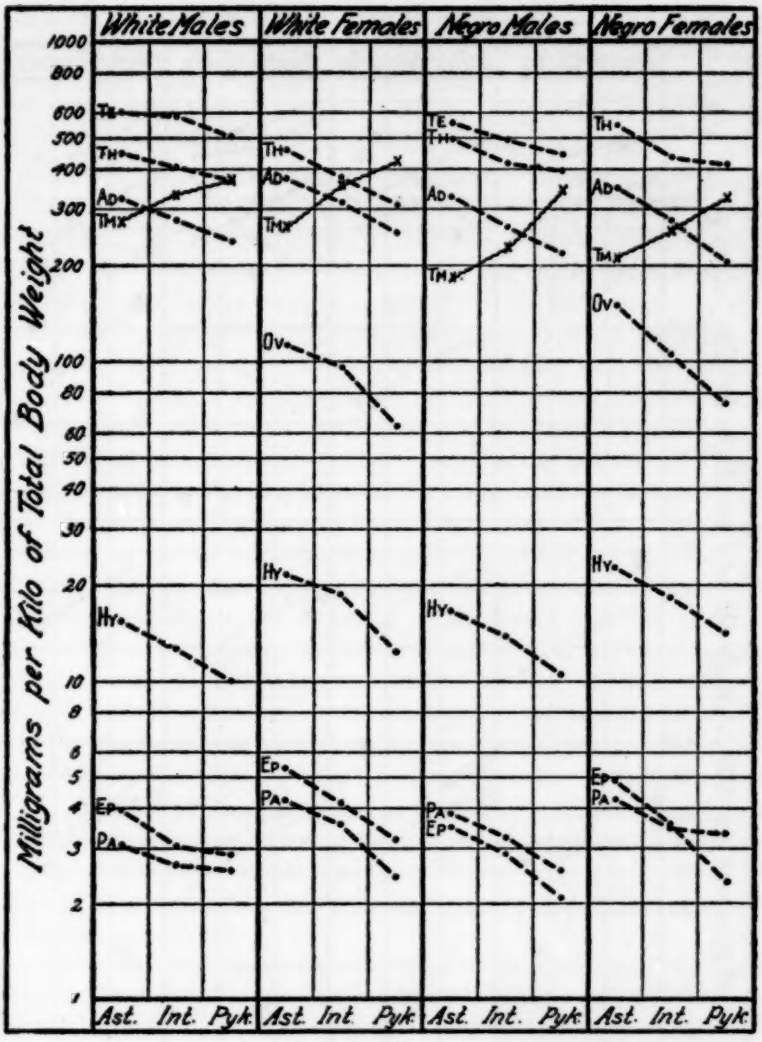

FIG. 1. SHOWING THE QUANTITATIVE DOSAGE OF ENDOCRINE ORGAN TISSUE IN RELATION TO BODY WEIGHT (MILLIGRAMS OF ENDOCRINE ORGAN WEIGHTS PER KG. OF TOTAL BODY WEIGHT) IN THE THREE BODY HABITUS TYPES

In this diagram and in Fig. 2 the abbreviations have the following significance: AD =adrenals; EP = epiphysis; HY = hypophysis; PA = parathyroids; TE = testes; TH = thyroid; TM = thymus; OV = ovaries; Ast. = asthenics; Int. = intermediates; Pyk. = pyknics. The observed points are connected with broken lines to indicate that the variation between the points is not continuous.

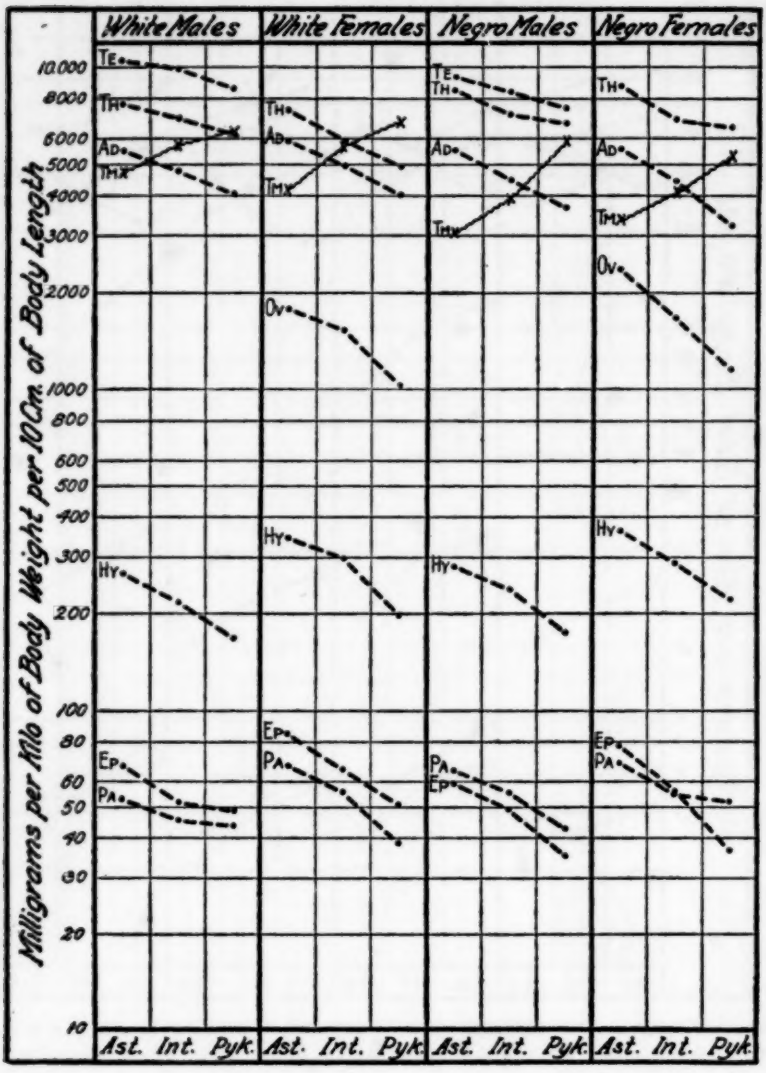

FIG. 2. SAME AS FIG. 1, BUT FOR MILLIGRAMS OF ENDOCRINE ORGAN WEIGHT PER KG. OF BODY WEIGHT PER 10 CM. OF BODY LENGTH

The data of Tables 15 and 16 are shown graphically in Figs. 1 and 2.

Tables 15 and 16 and Figs. 1 and 2 give a quantitative picture of the endocrine organ system pattern in the three defined types of bodily habitus. The thing that is most immediately striking about the results is their great regularity and inter-conformity in the four race-sex groups into which the material is divided. There are, broadly speaking, no exceptions to the general rule made apparent from the examination of any one group. We see exemplified in the clearest manner those general relations of endocrine pattern brought out in our earlier work.[2] Thus is seen the greater relative weight in proportion to body weight of the thyroid, adrenals, hypophysis, epiphysis, and parathyroids in the females as compared with the males in both whites and Negroes; the greater proportionate weight of the thyroids in the Negroes as compared with the whites in both sexes, etc.

But the most significant result that emerges is the uniformity of the trends of endocrine weights relative to body weight in the three "pure" bodily habitus types. The lines of Figs. 1 and 2 slope definitely *downwards* as we pass from asthenics through intermediates to pyknics for all but one of the endocrine organs, while for that one—the thymus—the line equally definitely slopes *upwards*. This means that *the average quantitative dosage of endocrine organ tissue per kg. of body weight is greatest in asthenics, less in intermediates ("athletics" of Kretschmer) and least in pyknics so far as concerns adrenals, thyroid, parathyroids, hypophysis, epiphysis, and gonads; while the relative dosage of thymus tissue is least in asthenics, greater in intermediates, and greatest in pyknics.*[21] As a comprehensive, whole picture of endocrine organ system pattern relative to bodily habitus types these results are, so far as we are aware, entirely novel, and appear to be of considerable importance in contributing to a more penetrating understanding of the physiology of somatological constitution.

In order that quantitative significance of the relationships just set forth between endocrine organ tissue and bodily habitus may be critically appraised Table 17 has been prepared. This table compares the two extreme habitus types—asthenics and pyknics—on the basis of the data

[21] It is, of course, to be kept in mind that the weight of the thymus gland does not by any means represent solely active glandular tissue, though in part it does. In our former paper (*loc. cit. supra*) Table 52 (p. 591) shows that the mean percentage of active glandular thymus tissue ranges, in different groups, from 4.99 percent to 30.31 percent. The remainder of the gland consists in considerable part of fatty tissue.

of Table 15. The discussion is confined to these extremes because of our conviction, as argued by Pearl[3] and others, that they alone appear to have definite and reasonably precise biological meaning. They represent the extreme expressions of the contrasting tendencies towards longitudinal and lateral growth. The intermediates are biologically only what the name implies, individuals in which the two contrasting growth tendencies are both represented in such degree as more or less to balance each other.

Table 17 is constructed in the following manner: The first column of figures for each of the four race sex groups gives the percentage which the difference between the asthenics and pyknics (as given in Table 15) is of the value for the asthenics, this percentage difference being given a minus sign (—) when the relative endocrine weight is *smaller* in the pyknics than in the asthenics, and a plus (+) sign when the relative endocrine weight is *greater* in the pyknics than in the asthenics. The second column of figures in each race-sex panel gives the ratio Difference/Prob. error of difference for the *absolute* (not percentage) difference between the means for asthenics and pyknics as given in Table 15. An example will make precisely clear how Table 17 was constructed and is to be read: The asthenic Negro females show in Table 15 a mean of 150 ± 9.7 milligrams of ovaries per kg. of body weight, and the pyknic Negro females a mean of 74 ± 8.7 milligrams. $150 - 74 = 76 \pm 13.0$ mgm., the absolute difference. $7600/150 = -50.7$, the *percentage* difference shown in the appropriate cell in the first column of the Negro female panel of Table 17. $76/13 = 5.8$, the value entered in Table 17 under "Error ratio."

The results set forth in Table 17 are plain and convincing. In every one of the 32 comparisons in this table the difference between the asthenic and pyknic mean relative endocrine organ weights is *more than three times its probable error,* and in all but a few cases a great deal more. *In percentage terms the pyknics differ from the asthenics in their relative quantitative endocrine equipment by amounts ranging from around 10 percent to over 90 percent.* The pyknics are relatively most *under-supplied* with adrenal, hypophysis, and epiphysis tissues as compared with asthenics, and most *over-supplied with thymus tissue.* Owing to the fact that in the case of all the other endocrine organs studied except the thymus the pyknics are relatively deficient as compared with the asthenics, it results that the pyknics have a smaller endocrine system in total per unit of body weight than the asthenics, the excess

TABLE 17

Percentage Differences and Ratio of Absolute Differences to their Probable Errors between Asthenics and Pyknics in Endocrine Organ Weights relative to Total Body Weight

GROUP	WHITE MALES		WHITE FEMALES		NEGRO MALES		NEGRO FEMALES	
	Percent. Diff.	Error Ratio	Percent. Diff.	Error Ratio	Percent. Diff.	Error Ratio	Percent. Diff.	Error Ratio
Total endocrine system	—10.6	5.1	—13.6	3.9	—10.3	3.1	—19.2	5.3
Adrenals	—25.9	9.7	—31.8	8.6	—32.7	7.1	—41.3	12.2
Thyroid	—18.5	5.6	—32.3	5.9	—20.4	4.2	—24.1	3.8
Parathyroids	—16.9	3.9	—42.8	8.7	—33.5	5.8	—22.3	3.2
Hypophysis	—34.6	17.1	—42.8	15.1	—37.3	13.5	—37.6	11.0
Gonads	—16.2	4.9	—43.8	5.3	—20.2	3.8	—50.7	5.8
Epiphysis	—26.8	6.9	—39.9	8.3	—40.1	6.8	—52.3	6.8
Thymus	+34.1	4.0	+60.8	5.3	+91.8	5.1	+55.0	4.4

of thymus weight in the pyknics not being alone able to compensate the accumulated relative deficiencies of the other organs. The relative deficiency of endocrine tissue in pyknics as compared with asthenics is greater in females than in males in respect of all of the endocrine organs showing pyknic deficiencies—i. e., all the organs except the thymus—save in the case of the Negroes relative to parathyroids. Relative to all the pyknic deficient endocrine organs the Negro males show greater percentage deficiencies than the white males. The Negro females exhibit greater percentage deficiencies than the white females in respect of adrenals, gonads, and epiphysis but smaller percentage deficiencies relative to the other pyknic deficient organs.

It is to be emphasized that the relations shown above between endocrine organ dosage relative to body weight are to be understood, on the present evidence, to be associative only and not necessarily causal. All that our evidence demonstrates is that particular quantitative endocrine system patterns are *associated* with the asthenic, intermediate, and pyknic bodily habitus types in this material. It is possible, perhaps even somewhat probable on general biological grounds, that the endocrine pattern may be in part causally involved in the demonstration of the somatic habitus characteristics of the individuals, but the essential point to be

remembered is that the purely biometric evidence we are able to present does not, and in the nature of the case, cannot *prove* this to be so. We think that we have conclusively demonstrated a definite association. It remains for other sorts of evidence, and particularly experimental evidence, to resolve the question as to whether the demonstrated association rests upon a causal relationship between the variables.

In the mean time it is interesting biologically to note that the pyknic, whose body build is plainly nearer to the infantile type in its general proportions and rotundity than that of either the asthenic or the intermediate, is supplied with a relatively great excess of thymus tissue in proportion to body weight as compared to the other two habitus types. While extremely little of a positive character is known regarding the true physiological function of the thymus or its secretion, there remains the broad fact of natural history that the thymus gland is at the height of its activity and size in infancy and childhood and begins to involute around the time of puberty; although it still contains active tissue throughout life.[22] Associated with the pyknic excess of thymus dosage relative to body weight are the relatively large deficiencies in relative dosage of adrenal, pituitary and pineal tissue in the pyknics.

We have not constructed a table corresponding to Table 17 from the data of Table 16 because it is obvious from a comparative study of Tables 15 and 16 that, primarily as a result of the rather high correlations between body length and body weight in the material, the only effect of introducing body length into the base for computing relative endocrine dosage as in Table 16, is to change the scale without in any essential way altering the interrelationships. Fig. 2 compared with Fig. 1 shows this clearly.

SUMMARY

The most significant result of this study, apart from numerous details reported, is to show that in a body of material including 1272 individuals the average quantitative dosage of endocrine organ tissue

[22] In this connection see the section on the thymus in our earlier paper[2]. In the light of the prevailing opinion that the thymus continues a process of degeneration or involution throughout life after puberty it is interesting to note from Table 2 that in all but one (white females) of the race sex groups the pyknics exhibit the highest average age. Yet the pyknics have the heaviest thymus glands per unit of body weight.

per kilogram of body weight is greatest in asthenics, less in intermediates ("athletics" of Kretschmer's terminology) and least in pyknics so far as concerns adrenals, thyroid, parathyroids, hypophysis, epiphysis, and gonads, while the average relative dosage of thymus tissue is least in asthenics, greater in intermediates, and greatest in pyknics. The differences between the extreme types, asthenics and pyknics, in mean weights of endocrine organs relative to body weight are generally large in amount, and without exception statistically significant having regard to their probable errors.

OPERATIONAL METHODS IN PROBLEMS OF FISSIPAROUS PROPAGATION

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IN THIS paper we are concerned with a population which maintains itself, from generation to generation, by the division of one or more members into a number of parts each of which becomes a member of the succeeding generation, and by the death of the number of the remaining members necessary to keep the population constant. Illustrations of this fissiparous process can be found in economic phenomena as well as in biological. It is precisely what occurs when one competitor absorbs another, the equivalent of saying, one divides and another dies.

The problem in which we are primarily interested is to calculate the probability of the existence of the population in some prescribed state in a future generation, assuming that its state in the initial generation is known. The theory which we develop will be applied to some related problems which suggest themselves[1].

I

The first case to be discussed is that of a population whose laws of propagation are the following:

a. In each generation one member dies and another divides.

b. The members of the population are of two kinds whose rates of death and division are the same.

c. New members are of the same kind as the member whose division produced them.

[1] Lotka has recently discussed problems which are related in a general way to those considered in this paper. *Journal Wash. Academy of Sciences*, Vol. 21, No. 16, Oct. 4, 1931, pp. 377-380; Vol. 21, No. 18, Nov. 4, 1931, pp. 453-459; HUMAN BIOLOGY, Vol. 3, No. 4, Dec. 1931, pp. 459-493.

The method of attack has something in common with that employed by Watson. Natural Inheritance, Francis Galton, 1889, p. 242.

If in the initial generation there are P members of the x kind and $N - P$ members of the y kind we shall call the function

$$S_0 = x^P y^{N-P}, \tag{1.1}$$

the state of the population in that generation. In the first generation the population will be in the state

$$\begin{aligned} S_1 = \frac{1}{N(N-1)} [&P(N-P)\, x^{P-1} y^{N-P+1} \\ &+ (P(P-1) + (N-P)\ (N-P-1))x^P y^{N-P} \\ &+ P(N-P)x^{P+1} y^{N-P-1}], \end{aligned} \tag{1.2}$$

where the coefficient of $x^K y^{N-K}$ represents the probability that the population in that generation will consist of K members of the x kind and $N - K$ of the y kind.

We next define the operator

$$\Delta = \frac{1}{N(N-1)} \left\{ x^2 \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial x \partial y} \right) + y^2 \left(\frac{\partial^2}{\partial x \partial y} + \frac{\partial^2}{\partial y^2} \right) \right\} \tag{1.3}$$

and observe that $S_1 = \Delta\, S_0$, and, more generally, that

$$S_r = \Delta^r S_0. \tag{1.4}$$

The first observation is immediate. The second follows from the fact that the coefficient of any term, $x^K y^{N-K}$, in S_r is the sum of the probabilities of the different sequences of events by which the population could become that one which has K of the x kind and $N - K$ of the y kind. Since these sequences are mutually exclusive the sum of their probabilities is the probability desired.

The infinite sum, $\Sigma = S_0 + eS_1 + e^2 S_2 + \cdots\cdots$, converges uniformly for $x, y \leqq 1$ and $e < d < 1$. In fact it is a homogeneous polynomial of degree N, the coefficients being functions of e. If we apply the operator $1 - e\Delta$ to Σ we obtain a differential equation

$$\Sigma - e\Delta\Sigma = S_0, \tag{1.5}$$

a consequence of (1.4).

The solution of this equation is unique if we limit ourselves to homogeneous polynomials of the N-th degree, $\Sigma = \sum_{n=0}^{N} A_n(e) x^n y^{N-n}$.

If the solution can be found and expanded in powers of e then the coefficient of e^r will be S_r. We substitute this polynomial in (1.5) and, by equating coefficients of $x^n y^{N-n}$, obtain the equations

$$(1.6)\qquad \begin{aligned} &A_n - \lambda\{(A_{n-1}\ (n-1)\ (N-n+1) \\ &+ A_n(n(n-1) + (N-n)\ (N-n-1)) \\ &+ A_{n+1}(n+1)\ (N-n-1)\} = \delta_P{}^n,\ n = 0, 1, \ldots, N, \end{aligned}$$

where $\lambda = e/N(N-1)$, and $\delta_P{}^n$ is the Kronecker symbol.

The determinant of this system is $D = |\, d_{ij}\,|$, where

$$(1.7)\qquad \begin{aligned} d_{n,n} &= 1 - \lambda\,(n(n-1) + (N-n)\ (N-n-1)), \\ d_{n,n+1} &= -\lambda\ (n+1)\ (N-n-1), \\ d_{n,n-1} &= -\lambda\ (n-1)\ (N-n+1), \\ d_{n,j} &= 0,\ j \neq n-1, n, n+1. \end{aligned}$$

Since $d_{i0} = \delta_i{}^0(1 - \lambda N(N-1))$ and $d_{iN} = \delta_i{}^N(1 - \lambda N(N-1))$ we can put

$$(1.8)\qquad D = D'(1 - \lambda N(N-1))^2$$

where D' is the determinant formed by removing the first and last rows and columns from D.

In order to factor this determinant we make use of the fact that if each column is multiplied by the proper coefficient and added to the first a factor of the determinant will appear as a factor of the new first column. If $H_n(d)$ is the multiplier of the n-th column for the d-th factor we find that the following difference equation must be satisfied by the multipliers

$$(1.9)\qquad \begin{aligned} &H_{n-1}\ (n-1)\ (N-n+1) + H_n\ (-2n(N-n) + N^2 - N - t_d) \\ &+ H_{n+1}\ (n+1)\ (N-n-1) = 0, \end{aligned}$$

where $1 - \lambda t_d$ is the d-th factor of D'.

We may take $H_1 = 1$ and seek a solution of the form $H_n = \sum_0^n h_k(n-1)^{(k)}$, where $h_0 = 1$, and $(n-1)^{(k)}$ indicates the product $(n-1)\ (n-2)\ \ldots\ (n-k)$*. On substituting this in equation (1.9) we find that

* Nörlund, Differenzenrechnung, p. 353 *et seq.*

$h_{k+1}\,(k+1)\,(k+2)\,(N-k-2) = h_k(t_d-(N-k-2)\,(N+k+1))$.

The sequence, h_k, terminates with h_{d-1} if $t_d = (N-d-1)\,(N+d)$, $d = 1, \ldots, N-2$. If $t_d = 0$, the sequence is infinite but summable, giving $H_n = (n-N-1)^{(n-1)}/n!$ which, by direct substitution, can be shown to satisfy (1.9). For any other value of t, h_{N-1} becomes infinite if $h_0 \neq 0$.

Combining the results of the preceding paragraph with (1.8) we have, finally,

(1.10)
$$D = \Pi\,(1-\lambda(N(N-1)-d(d-1)),\ d = 0, 1, 2, \ldots, N,$$

a polynomial of degree N in λ.

We shall now represent by $C_Q(\lambda)$ the determinant D with the Q-th column replaced by the right-hand members of (1.6), that is $c_{jQ} = \delta_j^P$. Employing partial fractions, we have

$$(1.11)\qquad \frac{C_Q(\lambda)}{D(\lambda)} = \sum_{n=1}^{N} \frac{B_{nQ}}{1-\lambda(N(N-1)-n(n-1))}$$

where

$$(1.12)\qquad B_{nQ} = \frac{C_Q\left(\dfrac{1}{N(N-1)-n(n-1)}\right)}{\Pi\left(1-\dfrac{N(N-1)-j(j-1)}{N(N-1)-n(n-1)}\right)},\quad j \neq n.$$

It should be noted that it will always be possible to cancel from C_Q and D at least one of the factors $1-\lambda(N(N-1))$, and that, as a consequence, there are not more than N partial fractions.

By expanding the partial fractions in power series and replacing λ by $e/N(N-1)$, we obtain the expression

$$(1.13)\quad A_Q = \frac{C_Q(\lambda)}{D(\lambda)} = \sum_{r=0}^{\infty} \sum_{n=1}^{N} B_{nQ} \left[\frac{(N(N-1)-n(n-1)}{N(N-1)}\right]^r .e^r$$
$$= \sum a_{Qr}e^r.$$

The coefficient of e^r in this expansion, a_{Qr}, represents the probability that the population originally in the state of P of the x kind

and $N - P$ of the y kind has Q of the x kind and $N - Q$ of the y kind in the r-th generation.

II

The results which we have just obtained enable us to solve the following problem: In a population of N members, all different, to find the probability that in the r-th generation they will all be descendants of a single one of the original members. Since the events are mutually exclusive this probability is N times the probability that they will be descendants of a particular one of the original members.

We shall represent this probability by E_r and let the superscript 1 indicate that $P = 1$ for this problem. From (1.13) it follows that $E_r = N\, a^1_{Nr}$. The numerator, $C'_N(\lambda)$, reduces to $((N-1)!)^2\lambda^{N-1}$, and the coefficients, by (1.12), become

$$(2.1)\quad B^1_{nN} = \frac{(-1)^{n-1}((N-1)!)^2(2n-1)}{(N-n)!(N+n-1)!},\ n = 1, 2 \ldots, N.$$

Finally, by (1.13), we find,

$$(2.2)\quad E_r = Na^1_{Nr} =$$

$$N \sum_{n=1}^{N} \frac{(-1)^{n-1}\ ((N-1)!)^2(2n-1)}{(N+n-1)!(N-n)!} \left[\frac{(N+n-1)\ (N-n)}{N(N-1)}\right]^r.$$

It can be shown that E_r approaches 1 as r becomes infinite and we conclude: The population tends to a state in which all of the members are descendants of one of the original members.

The probability that the population achieves this state in the r-th generation can now be calculated. It is found to be

$$(2.3)\quad E_r - E_{r-1} = N \sum_{n=1}^{N} \frac{(-1)^n((N-1)!)^2(2n-1)}{(N+n-1)!(N-n)!} \quad \frac{n(n-1)}{N(N-1)}$$

$$\left[\frac{(N+n-1)\ (N-n)}{N(N-1)}\right]^{r-1}.$$

The mean number of generations necessary for the population to attain this state is given by

$$(2.4)\quad \sum_{1}^{\infty} r(E_r - E_{r-1})$$

$$= N \sum_{n=2}^{N} \frac{(-1)^n((N-1)!)^2(2n-1)}{(N+n-1)!(N-n)!} \frac{n(n-1)}{N(N-1)}$$

$$\left[\frac{1}{1-\frac{(N+n-1)(N-n)}{N(N-1)}}\right]^2$$

$$= N \sum_{n=2}^{N} \frac{(-1)^n((N-1)!)^2(2n-1)}{(N+n-1)!(N-n)!} \frac{N(N-1)}{n(n-1)}.$$

In order to evaluate this sum we introduce the auxiliary quantity

$$R(N) = \sum_{n=2}^{N} \frac{N!(N-1)!}{(N+n-1)!(N-n)!} (-1)^n \frac{(2n-1)}{n(n-1)},$$

whose first difference is

$$R(N) - R(N-1) = \sum_{n=2}^{N} \frac{(N-1)!(N-2)!}{(N+n-1)!(N-n)!}(-1)^n(2n-1).$$

Grouping the terms in an appropriate manner this difference may be written as

$$R(N) - R(N-1) =$$

$$\left\{ \sum_{n=0}^{N-2} \frac{(-1)^{N-n}(N-n)}{(2N-1-n)!n!} + \sum_{n=N+1}^{2N-1} \frac{(-1)^{N-n}(N-n)}{(2N-1-n)!n!} \right\}$$

$$(N-1)!(N-2)! = \frac{(-1)^{N+1}(N-1)!(N-2)!}{(2N-1)!}$$

$$\left| \frac{d}{dx} \left\{ (1-x)^{2N-1}x^{-N} - \frac{(-1)^{N-1}(2N-1)!}{(N-1)!N!} (x^{-1}-1) \right\} \right|_{x=1}$$

When the derivative in the last expression is evaluated we find

$$R(N) - R(N-1) = \frac{1}{N(N-1)} = -\frac{1}{N} - \frac{(-1)}{N-1}.$$

From this it follows that $R(N) = -\frac{1}{N} + \frac{1}{2} + R(2)$. But $R(2)$ is $\frac{1}{2}$ and we have finally $R(N) = (N-1)/N$.

Since $\sum_1^n r(E_r - E_{r-1}) = R(N)N(N-1)$ we obtain the result: The mean number of generations for a population to reach the state in which it consists of descendants of one of the original ones is $(N-1)^2$.

III

This operational method can be easily extended to cover more general laws of propagation. If we wish to consider a population in which r_0 members die, r_1 remain inert and r_k each divide themselves into k members the differential operator (1.3) is replaced by

$$\frac{\Pi\left(x^k \frac{\partial}{\partial x} + y^k \frac{\partial}{\partial y}\right)^{r_k}}{N!}, \tag{3.1}$$

$$\Sigma\,(k-1)r_k = 0, \quad \Sigma\, r_k = N.$$

In writing the operator in this symbolic form it is understood that the differentials do not operate on the coefficients of the other factors but only on the quantity to which the operator is applied.

NOTES

APOLOGY

DUE to a regrettable oversight, for which I assume full responsibility, it was not stated that the article "Vital Data on the Seminole Indians of Florida and Oklahoma", which had its original publication in HUMAN BIOLOGY, Vol. 7, No. 3, 335-349, Sept. 1935, will form part of a detailed report on "The Physical Anthropology of the Seminole Indians of Oklahoma" presently to be published by the Comitato Italiano per lo Studio dei Problemi della Popolazione, Rome, Italy. To the Italian Committee and the editors of HUMAN BIOLOGY my sincere apologies.

W. M. KROGMAN

RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

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